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REHABILITATION

EDWARD W. LOWMAN, M.D., *Guest Editor*

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Foreword

Fabian Bachrach

EDWARD W. LOWMAN, M.D.

Twenty-five years ago when I chose to enter the field of rehabilitation medicine, it was because of the urgent need for rehabilitation services for the World War II battle casualties filling naval as well as other military hospitals. There was no specialty board then and, indeed, little medical understanding or respect for this bastard child of "physiotherapy." Mine, like most medical curricula of those times, had included a 1 hour tour demonstration of therapy lamps, electrical machines, and water tanks in the hospital basement titularly under the director of the x-ray department. The impression was as evanescent as my exposure to and training in the management of arthritis, hemiplegia, and other chronic disabling diseases.
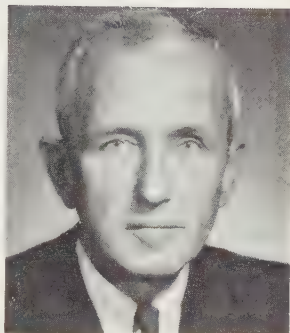
But the reasons were not without justification, for these were the closing years of the era of acute infectious disease mortality. The first of the sulfonamide drugs was just being put to clinical trial. The pneumonia jacket was still a valued therapeutic aid. Syphilis, typhoid, gonorrhea, osteomyelitis, and the whole spectrum of bacterial infections with their major threats to life demanded prime priority both in hospital bed occupancy and of one's medical time and skills. Little wonder that in those days rehabilitation medicine loomed alien and strange with its emphasis and dedication to comprehensive health care for the chronically ill and the physically disabled.

The chemotherapy revolution of the 1940's and casualties of World War II precipitously and with mutually complementary timing catalyzed a change in the face of medicine. Howard Rusk was the father of rehabilitation medicine in its present context. His remarkable program in the Army Air Force was an educational milestone in crystallizing and

demonstrating truly comprehensive medical care and human salvage through rehabilitation.

By 1947, the progeny had grown sufficiently in stature for it to attain recognition as a distinct specialty, and, largely due to the leadership of Frank Krusen, the American Board of Physical Medicine was born.

Now, after a quarter of a century in this specialty devoted to comprehensive care, it is gratifying to see the concept come of age. For, today, "comprehensive care" is chic and sophisticated lingo enunciated by some as if a startlingly fresh vision. Its impact is apparent in federal medical programs, in medical curricula, in the responsible reaching out of hospitals to the community, in chronic disease care, and, of course, in the explosive demand for the services of specialists in the field of rehabilitation medicine. This latter need looms with such enormity that it can never be met in any predictable future. The number of specialists certified by the American Board of Physical Medicine and Rehabilitation to date is just in excess of 500. A recent estimate from a study by the Commission on Education in Physical Medicine and Rehabilitation of the *present* need was 3500 with a projected need in 1975 of 7000. Despite more than 50 residency training programs across the country (including that in New York University, which is the largest, with more than 50 residents), the output far from satisfies the demand. The dilemma has thus changed into one of pleasant position but deeply disturbing perplexity.

In an effort to even partially decompress the problem, the American Board now allows a year of credit for formal training in any other specialty, thus reducing the required formal Rehabilitation Medicine training time to 2 years in such instances. More recently, it is allowing 1 year of credit for general practice experience of 4 years or longer, thus similarly shortening the training time for physicians in general practice desiring specialization. The results of the latter, in my experience, have been highly successful, for the practice of rehabilitation medicine requires sound medical experience, mature judgment, and a responsible concern for patients as people, attributes which the experienced physician has acquired in the course of his practicing. Finally, in support of these efforts to resolve the manpower shortage, the Social and Rehabilitation Service of the Department of Health, Education and Welfare provides generous trainee fellowships to qualified physicians acceptable for training in these approved residency programs.

Thus has rehabilitation medicine come of age in this day of comprehensive health care needs. That it is a widely comprehensive specialty is patently obvious in the broad range of the subject content of this volume. Its focus, however, is the patient, and its effectiveness is in direct proportion to one's skill in recognizing and dynamically meeting the total needs of his patient despite the residual disability and its implications within his life pattern.

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Evaluation and Habilitation of Patients with Spina Bifida and Myelomeningocele

During the last 20 years, there has been increasing interest in the etiologic, pathophysiologic, biochemical, and developmental aspects of birth defects, and a corresponding interest in the comprehensive medical management of children with such defects. There is evidence that more than 50 per cent of the children admitted for hospital care require that care either primarily or secondarily for problems related to birth defects.

Improved medical and surgical care for the neonate, infant, and child has markedly improved the chances for survival of children with certain birth defects, with a resultant increase in the prevalence of the defect even though the incidence is apparently unchanged. An example of this circumstance is provided by the increasing prevalence of children and adults with spina bifida manifesta. This is directly related to the improved survival rate which has resulted from an effective program of comprehensive medical care.

Spina bifida manifesta presents a quadrad of serious disabilities (paraplegia, incontinence of bowel and bladder, sensory loss, and hydrocephalus [60 per cent of patients]), which can most effectively be managed by a closely integrated group of medical and paramedical specialists working cooperatively with the patients. Such a group representing seven departments of New York University was organized more than 10 years ago. In the following pages some of the members of this study group will briefly review selected aspects of this birth defect and outline methods of medical management and habilitation.

The Birth Defect and the Pediatric Problems It Presents

CHESTER A. SWINYARD, M.D., Ph.D.*

CLAUDE SANSARICQ, M.D.**

The term "spina bifida" refers to a developmental failure of the laminar processes of one or more vertebrae to fuse in the midline and form a single dorsal spinous process (Figs. 1A and 2A). There are several anatomical varieties of spina bifida, which are delineated in Table 1.

Spina bifida occulta occurs in more than 50 per cent of the adult population.[9] It is not visible; it may be palpable, but can be verified only by roentgenogram (Fig. 2B). This type of spina bifida generally presents no clinical symptoms.[12]

Spina bifida manifesta can be recognized visually by the presence of a translucent white or bluish white sac which generally protrudes through the skin but may be covered with skin (Fig. 1). If the spinal cord

Table 1. *Differentiation of the Anatomical Types of Spina Bifida and the Problems Associated with Them*

I. Spina bifida occulta
  A. Failure of one or more vertebral laminae to fuse in the midline. Affects 50 per cent of the population. Usually no clinical symptomatology (Fig. 2B).
II. Spina bifida manifesta
  A. Spina bifida with meningocele (4 per cent of the cases of spina bifida manifesta).
    1. A fluid-filled sac visible in the lower back (90 per cent lumbosacral) containing nerve roots (Fig. 3).
    2. Spinal cord developed normally.
    3. Minor to moderate degrees of muscle paresis or bowel and bladder incontinence.
  B. Spina bifida with myelomeningocele (96 per cent of the cases of spina bifida manifesta).
    1. Failure of the spinal cord to form a tube. Defective spinal cord on the surface of or within the wall of the sac. May leak cerebrospinal fluid (Figs. 1B and 2C).
    2. A quadrad of serious signs and symptoms:
      a. Muscle weakness below defect.
      b. Sensory loss below defect.
      c. Hydrocephalus (65 per cent of patients).
      d Incontinence of bowel and bladder.

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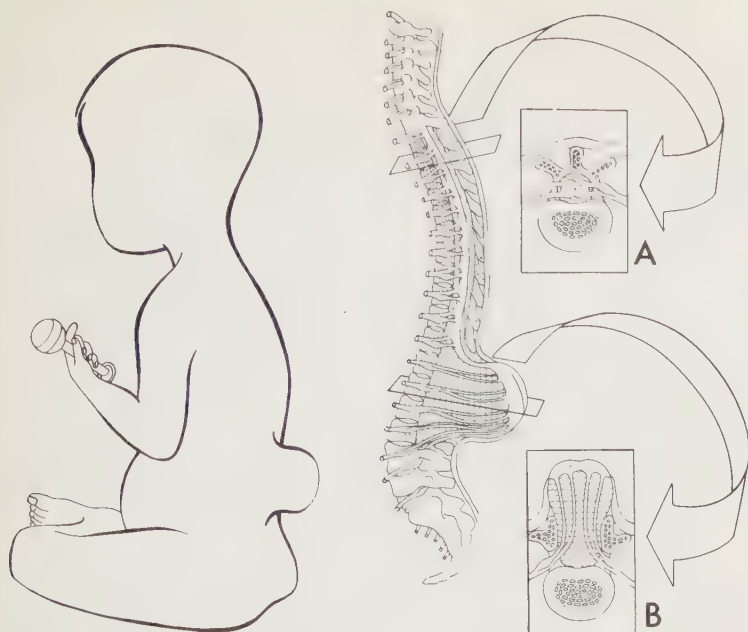
Figure 1. The diagram on the right illustrates the vertebral column and spinal cord of the baby shown on the left. *A*, Cross section of the normal upper part of the spine. *B*, Cross section of the lower part of the spine showing incompletely developed vertebrae and spinal cord.
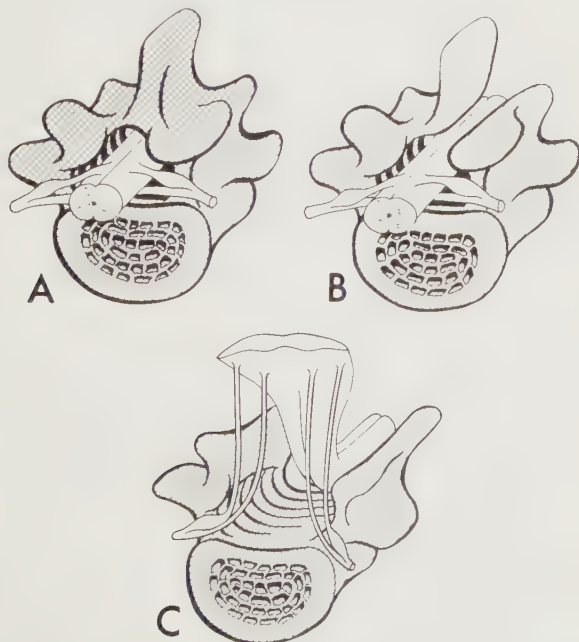
Figure 2. *A*, Normal vertebral and spinal cord development. *B*, Incomplete vertebral development, but properly formed spinal cord (spina bifida occulta). *C*, Incomplete development of the vertebrae with flat, protruding spinal cord plate (spina bifida manifesta). In all three diagrams, the spinal cord is shown in white. The nerves are indicated by the forked tubelike extensions on either side.
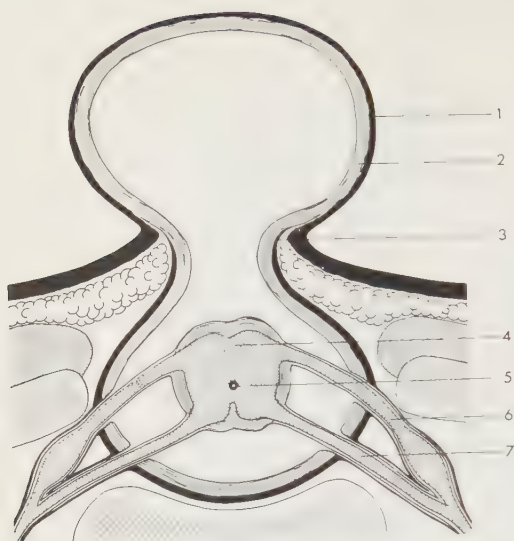
Figure 3. Spina bifida with meningocele (adapted from Leveuf, Bertrand, and Sternberg). (1) Epidermis. (2) Meninges. (3) Dura mater. (4) Spinal cord. (5) Central canal. (6) Dorsal root. (7) Ventral root.

is normally developed and only the roots of lumbosacral nerves are involved in the sac, the defect is referred to as a meningocele (Fig. 3). These patients have relatively minor degrees of muscle weakness. This variety of spina bifida includes only 3 or 4 per cent of patients with spina bifida manifesta. The second type of spina bifida manifesta is associated with myelomeningocele (Figs. 1B and 2C). These patients comprise about 96 per cent of the cases of spina bifida manifesta and have a serious developmental defect of the spinal cord which occurs during the third to fourth week of fetal life. The thickened ectodermal anlagen of the spinal cord (medullary plates) fails to elevate and form a tubular spinal cord (Figs. 1B and 2C). At the level of the defect, the spinal cord is a flat, irregularly shaped plate which may be in the meningeal sac or on the body surface. In the latter case, cerebrospinal fluid flows over the exposed surface of the neural plate. Patients with such defects are confronted with muscle weakness, incontinence of bowel and bladder, sensory loss, and hydrocephalus.

The Incidence of Spina Bifida with Myelomeningocele

Myelomeningocele occurs in nearly 2 of every 1000 live neonates. On this basis, there may be 8000 to 10,000 newborns with this defect delivered annually in the United States. For reasons unknown, the incidence in Ireland, Scotland, and Wales is significantly higher than in the United States.[12]

Some Ecological Considerations

Spina bifida is more common in females than males (1.25:1).[6] It appears to be less frequent in nonwhite populations[3] and in Jews.[7] It is more frequent in urban than in rural areas,[2] and more frequent in lower socioeconomic groups.[2] There does not appear to be any relationship to maternal parity[3, 10] (except in the first child and after the sixth), age,[7, 10] or employment.[10]

Apparently myelomeningocele represents a complex interaction of the genetic constitution and the fetal environment. The findings in twins are against any substantial genetic influence;[5] however, in a family with one affected child, the chances of a second similar newborn rise to 5 per cent. If there are two affected children, the chance of a third occurrence is approximately 15 per cent.[1] Although there has been much speculation about environmental factors of etiologic importance, none have thus far been identified.

Pediatric Care of the Child with Spina Bifida

One of the most important initial functions of the pediatrician is to begin proper education and counselling of the mother and the family. There is a distressing tendency to call for neurosurgical consultation with reference to primary surgery on the meningeal sac and wait for the parents to learn by experience of the orthopedic and urologic problems. Habilitation is completely dependent upon the understanding of the infant's problems and the parents' acceptance of him. It is helpful to have the parents join a spina bifida parent group. We have prepared a manual for parents[11] which has been useful.*

The pediatrician must be alert to signs of infection (septicemia, for instance) and increased intracranial pressure. If a ventriculocardiac or other type of shunt has been performed, the infant must be observed closely for signs of shunt obstruction or malfunction.

Spina bifida is not a contraindication to the usual immunization program, including booster shots. Children with brain damage from hydrocephalus may be prone to develop pertussis and post-measles encephalitis; therefore, the comprehensive immunization program becomes even more important in these children.

The parents will not be concerned about bowel and bladder incontinence during the first year of life because this is a characteristic feature of normal children. However, they should be informed about this facet of the disability and assured that ways and means are available to make the child hygienic and socially acceptable. The parents will need special help with the incontinence problem near the end of the first year.[8]

Bowel incontinence occurs as a result of impaired innervation of portions of the large bowel, rectum, and sphincter ani externus muscle. The impaired innervation prevents initiation of neural reflexes that discharge the fecal contents, which become dehydrated and cause constipation or impaction. Bowel incontinence is easier to manage than urinary incontinence and does not engender the life-threatening secondary changes that occur in urinary incontinence.

Bowel habit varies so much between different persons that one cannot speak of specifics of treatment. In general, management is related to dietary intake, administration of stool softeners or mild cathartics, and use of rectal suppositories. One can generally achieve a daily evacuation on schedule.

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*Available gratis from Association for the Aid of Crippled Children, 345 East 46th Street, New York, New York 10017.

Intellectual Development

In the absence of hydrocephalus, the child has no organic brain damage, and intellectual development may proceed as it does in normal children. However, if the child is severely physically handicapped, and the family does not provide him with socializing and other varieties of environmental stimulation and motivation, there may be some retardation on the basis of psychosocial deprivation.

Those children with a history of hydrocephalus without treatment of this problem score lower in psychologic testing and present significant discrepancies between verbal and performance scores.[1]

Since hydrocephalus occurs more frequently in patients with higher lesions, the more severely involved children from the motor point of view also have a greater likelihood of developing hydrocephalus and resultant intellectual retardation. However, the degree of retardation is not severe and with uncommon exceptions the children are educable.

Summary

It is the responsibility of the pediatrician, or whichever physician assumes over-all charge of the child, to advise that an orthopedic surgeon and physiatrist see the infant in the neonatal period, and that urological surveillance must begin at approximately 6 months of age. Details of these specialized services are given in the following contributions.

During periods of rapid growth in childhood and adolescence, one must be particularly aware of the possibility of developing orthopedic deformities. The over-all goal of the medical program is to prevent as much deformity as possible, to train the child to be physically independent in activities of daily living, and to keep him hygienic and socially acceptable so that he can gain admission to a regular school. If these goals are attained and effective neurosurgical care has prevented or minimized brain damage from hydrocephalus, many of these children will reach adult life with a good educational background and excellent vocational potential.

Neurosurgical Management of Patients
with Spina Bifida and Myelomeningocele

JOSEPH RANSOHOFF, M.D.*

ERNEST S. MATHEWS, M.D.**

Central nervous system problems are of primary importance in newborns with myelomeningocele. The neurosurgical decisions and actions in this early period not only affect the chances of the patient's survival but, in many instances, may either limit or facilitate the effectiveness of care which can be offered by other medical or surgical specialists.

The problems of immediate concern which, to a great extent, determine the newborn's rehabilitation potential are the following:

1. Decision about surgical closure of the myelomeningeal sac.

2. Evaluation of the dynamics of cerebrospinal fluid production and absorption: Assessment of ventricular enlargement and detection of signs of increased intracranial pressure and active hydrocephalus.

3. Evidence of central nervous system infection or leakage of cerebrospinal fluid.

4. Level and length of the myeloschitic section of the spinal cord, with special reference to both motor impairment and technical feasibility of the surgical repair.

Timing of the Primary Surgery

Sharrard[7] advocates closure of the spinal sac as an emergency procedure during the first 48 hours of life. His study indicated that immediate surgical closure decreased mortality, reduced the incidence of local infection and ascending meningitis, and shortened the hospital stay. Sugar and Kennedy[8] presented electromyographic evidence that early surgery might prevent some loss of muscle power by denervation. On the other hand, Matson[6] does not recommend routine closure of the defect. The level of the lesion, size and shape of the defect, and socio-economic factors enter into his decision. Matson states, "When examination on the first day of life, therefore, confirms the total absence of neurologic function below the upper lumbar levels, custodial care is recommended."

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Laurence[1] has shown that, without treatment, progressive hydrocephalus accounts for much of the mortality of these infants in the first months of life. In our experience, custodial care is not generally accompanied by effective medical treatment, nor do these neglected infants, sent off to die, necessarily succumb. They commonly survive and develop marked hydrocephalus with impaired intellectual capacity.[1] The presence of the sac limits variation in bed posture and contributes directly to development of orthopedic deformities. Furthermore, the myelomeningeal sac frequently interferes at a later date with application of bracing which would enable the patient to sit and stand.

Realizing the enormity of the socioeconomic and psychological problems involved, it has, however, been our policy to close the spinal defect in all infants as soon as possible if it is technically feasible.[2]

Initial Evaluation

Initial neurosurgical assessment of the patient includes the following procedures:

1. X-ray of the spine, skull, and chest.
2. Neurological assessment of the length and level of the defect on the basis of motor response and sensory loss.
3. Spinal fluid examination derived from ventricular puncture.
4. Clinical evidence of increased cerebrospinal fluid pressure or hydrocephalus.
5. Determination of ventricular size at the time of ventricular puncture.
6. Air encephalography in rare instances when central nervous system abnormalities other than hydrocephalus are suspected.

If the evaluation indicates evidence of cerebrospinal fluid infection, the offending organism is identified by cerebrospinal fluid smears and culture. The proper antibiotic regimen is determined by sensitivity testing. We have described details of our antibiotic treatment program elsewhere.[2] It is our policy to treat the infection first, and primary defect surgery or shunt surgery is deferred until the infection is controlled.

Management of Hydrocephalus

Approximately 60 per cent of the patients with myelomeningocele develop overt hydrocephalus, which, if untreated, contributes significantly to the high mortality in the first year of life or seriously impairs cognitive functioning. However, Lorber[5] has shown that head circumference is not a reliable index of the presence of active "hydrocephalus." It is for this reason that the initial evaluation includes echoencephalography and, at times, air ventriculography for detection of ventricular enlargement and site of cerebrospinal fluid blockage.

In the presence of active hydrocephalus and freedom from infection, we elect to perform a ventriculoatrial shunt with either a Holter or Pudenz shunt tubing (Fig. 4) in all infants with progressive ventricular enlargement, before considering repair of the meningomyelocele. Although these shunting procedures have saved lives and preserved intellectual function in many children, certain difficulties are inherent. Growth of the patient, obstruction of the shunt, and infection necessitate frequent shunt revision. A large percentage of the patients eventually

become "shunt dependent."[3] In the child with both active hydrocephalus and meningomyelocele, therefore, the former is treated with a shunting operation. Often the meningomyelocele thereafter collapses and heals solidly without the need for further surgery. If not, secondary meningomyelocele repair is carried out, in conjunction with our plastic surgeons if necessary.

During the last several years, in collaboration with the bioengineering department of the Republic Aviation Division, Fairchild Hiller Corporation,* we have been involved in the development of a mechanized pump which appears to have the potential to obviate some of the difficulties encountered with the conventional shunting procedures.[9] There are laboratory data which indicate that hydrocephalus is related more to net fluid volume exchanged than to pressure dynamics. Our experimental model consists of a miniature pump implanted within the skull which transfers fluid from the ventricular system into the superior sagittal sinus at adjustable rates from 1.4 to 5.7 ml. per hour independent of pressure. The pump is activated by a magnetic coupling effected when a small induction motor is superimposed over the pump on the surface of the scalp. This technique is still in the developmental stage.

Figure 4. Diagrammatic representation of a surgical method of arresting progressive hydrocephalus: a ventriculojugular shunt. Cerebrospinal fluid under abnormally high pressure in the brain is redirected into a great vein above the heart by means of a small flexible tube. This procedure reduces the fluid pressure in the brain.

Labels in figure: Brain, Skull, Shunt (flexible tube), Ventricles, Valve, Jugular Vein, Heart, Lung
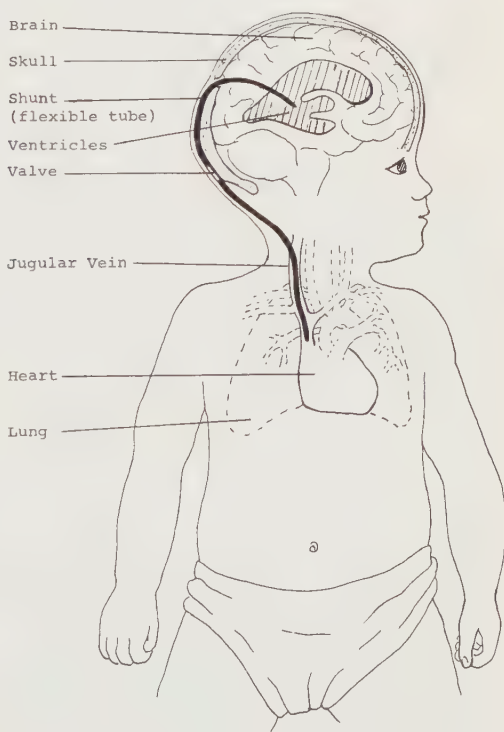
Summary

The survival rate and rehabilitation potential of patients with spina bifida associated with myelomeningocele are dependent upon a positive attitude and action program by neurosurgeons. We advocate primary closure of all spinal defects as early as possible, if they are technically amenable to closure. Comprehensive neurological evaluation is essential for early detection of ventricular enlargement and active hydrocephalus which should be controlled when possible. All surgical procedures should be deferred until central nervous system infection is controlled.

Urologic Management of Children with Myelomeningocele

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The urologic problems in children with myelomeningocele have their origin in impaired innervation of the urinary tract. Most of the children have a so-called lower motor neuron type of neurogenic bladder.[2] The large majority of the deaths that occur in childhood, adolescence, and young adult life in patients with this defect result from renal failure related to distortion of the upper urinary tract and associated pyelonephritis (Fig. 5). Adherence to the urological management program which will be briefly mentioned in the following paragraphs has resulted in a significant reduction in morbidity and mortality in patients with this birth defect.

Urological Evaluation

Since one cannot restore the impaired neurologic deficit of the urinary tract, the objectives of management are to develop ways of keeping the incontinent child sufficiently hygienic to achieve social acceptance; to detect and control urinary tract infection and stone formation; and to prevent upper urinary tract distortion and dilatation which lead to chronic pyelonephritis and destruction of the renal parenchyma.[3]

The above objectives can be achieved only through periodic urologic survey. This evaluation should be done during the first year and annually thereafter for the rest of the patient's life. The annual survey includes the following tests and procedures:

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Intravenous pyelogram: Intravenous injection of radiopaque dye which is excreted promptly by normal kidneys. The dye injection is followed by timed x-rays which visualize the upper urinary tract. Objective: to indicate trends in progression or regression of upper urinary tract dilatation and assessment of renal function.

Cystourethrograms: X-rays following injection of radiopaque medium into bladder and urethra. Objective: to evaluate severity of bladder trabeculations and detect presence of reflux into ureters.

Urine culture and sensitivity of the contaminating bacteria to antibiotics. Objective: to determine urinary infection and assist in selection of an appropriate antibiotic for treatment of the infection.

Residual urine measurement: Measurement of amount of urine left in the bladder after voiding. Obtained by insertion of a catheter into the bladder after voluntary abdominal straining and application of Credé pressure to the bladder. Objective: to assess the extent of urinary outlet obstruction.

Problems of the Lower Urinary Tract

Residual Urine. The neurogenic bladder has impaired emptying ability, which necessitates manual expression of urine (downward and backward pressure over the bladder). This procedure is generally referred to as "Credé expression" (after K.S.F. Credé, German gynecologist, 1819-1892). In some children, the bladder can be quite completely emptied by this technique, but in many, a significant urinary residual remains which is prone to infection.
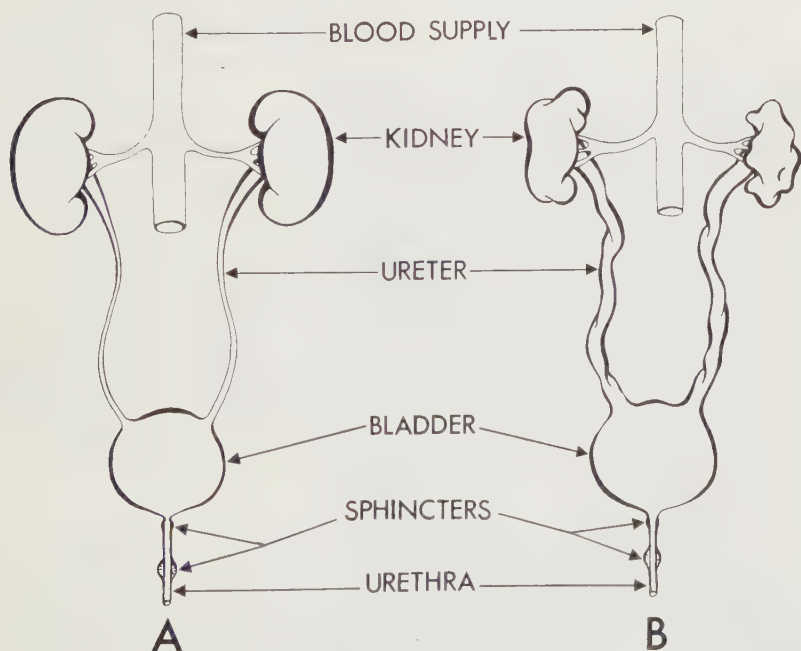
Figure 5. *A,* Normal, properly functioning urinary system. *B,* Damaged upper urinary tract.
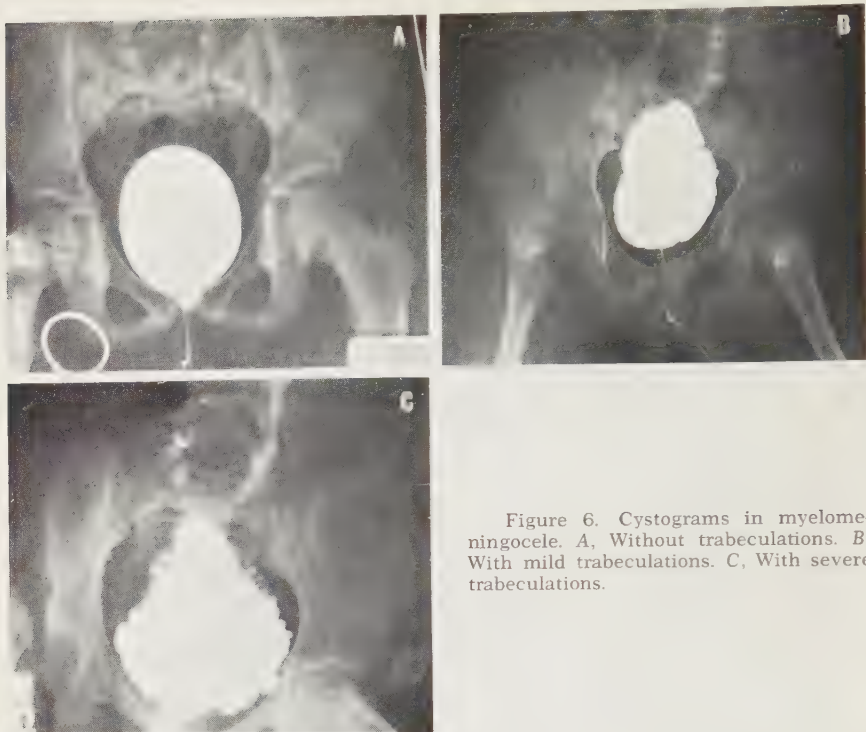
Figure 6. Cystograms in myelomeningocele. *A*, Without trabeculations. *B*, With mild trabeculations. *C*, With severe trabeculations.

INFECTION. Urinary stasis (residual urine) provides an ideal environment for proliferation of pathogens which exist in the urine. In children with myelomeningocele, a low-grade fever and malaise generally mean urinary tract infection. Infection is managed by culture and sensitivity tests on a midstream urinary specimen. Control of infection is generally achieved by prolonged treatment with antibiotics, preferably nitrofurantoin or long-acting sulfonamides. If the infection is frequently repetitive, efforts should be made to reduce urinary stasis by a Y-V plastic procedure on the vesical neck in young children or a transurethral resection of the vesical neck in older children. We have not found periodic prophylactic administration of antibiotics to be of value.

BLADDER TRABECULATION. The bladder responds to increased pressure from bladder obstruction by development of a network of elevated bands of detrusor muscle on the interior of the bladder. Visualization of this process by cystograms provides a better concept of the dynamics of bladder functioning (Fig. 6).

Problems of the Upper Urinary Tract

The ever-present danger of upper urinary damage is of great concern because the sequelae of this occurrence can be life-threatening. Assessment of the upper urinary tract is achieved by annual intravenous pyelogram (Fig. 7). With evidence of impending damage, this diagnostic procedure may need to be repeated at 6 month intervals and may result in need of urinary diversion.
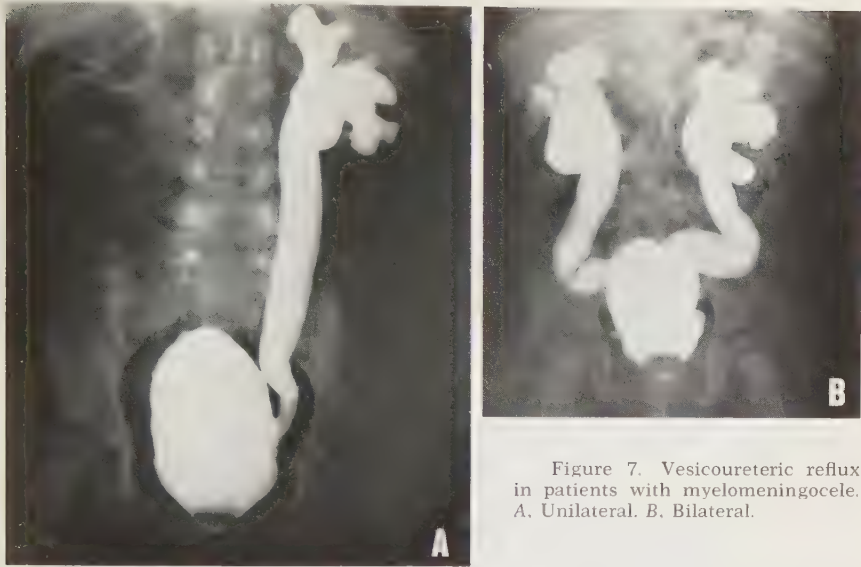
Figure 7. Vesicoureteric reflux in patients with myelomeningocele. A, Unilateral. B, Bilateral.

The operation of choice is ureteroileostomy (Bricker procedure). In this operation, the two ureters are transected and implanted into an isolated segment of terminal ileum. Bowel continuity is established by end-to-end anastomosis and the ileum is fixed in an opening in the right abdominal wall (Fig. 8). A urinary bag is cemented to the skin surround-

Figure 8. Urogram of spina bifida patient several months after ureteroileostomy (Bricker procedure).
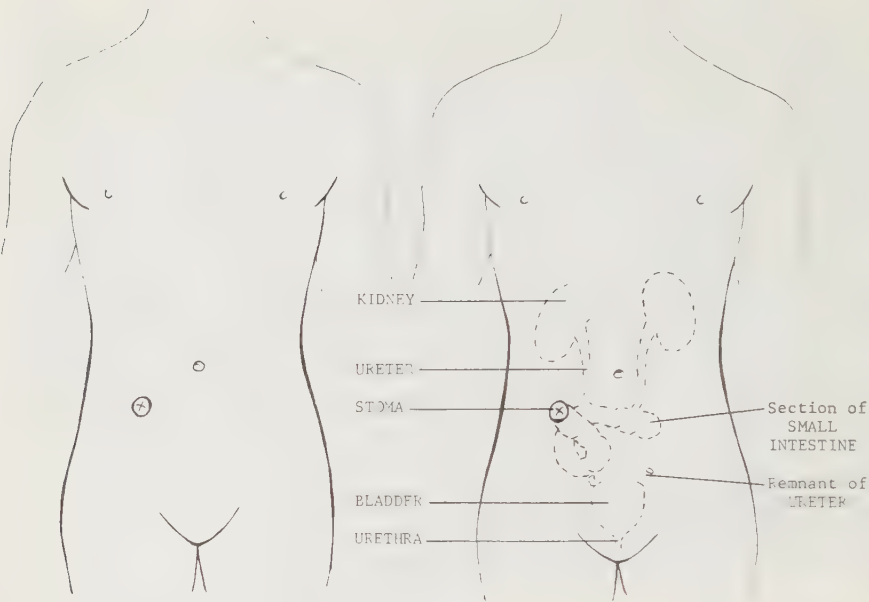
Figure 9. Diagrammatic representation of the Bricker procedure (ureteroileostomy).
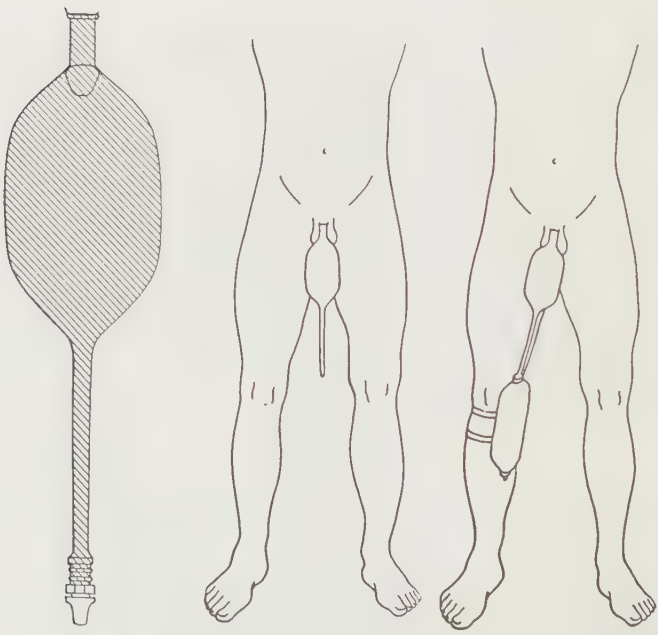
Figure 10.

ing the ileal stoma (Fig. 9) and the child soon learns to care for the collecting bag personally.

This operation lessens or arrests further upper urinary tract and renal damage. The outlook for the child is remarkably improved. Urinary incontinence is no longer a problem and the child becomes socially acceptable and can enter school.

Control of incontinence by ureteroileostomy is frequently performed before upper urinary tract problems develop. This is especially true in girls, because it is more difficult to keep incontinent girls hygienic. The operation is done in both sexes when it appears likely that the child can successfully manage the ileostomy bag, and the social circumstances make it difficult to achieve a continuously hygienic state through use of cellulose padding, deodorants, and rubber pants.

Control of incontinence in boys can usually be achieved by use of a properly fitted latex rubber penile sheath (child's urinary bag). This leads to a rubber reservoir on the thigh, which can be detached and emptied by the child (Fig. 10).[1]

General Principles of Bladder Management

We have avoided the use of the term "bladder training" because it implies that repetition of a urinary habit or technique might result in restitution of bladder function, a goal which cannot be achieved. However, it is possible to manage the incontinence by the various techniques mentioned previously so that the child is dry and hygienic.

These children should be maintained on a high fluid diet and showed how to empty the bladder by the Credé technique at regular intervals by the clock, since they lack sensation of bladder fullness.

Summary

Urinary incontinence is a sequel of neurogenic bladder caused by myelocele. Morbidity and mortality can be lessened by controlling urinary infection and preventing upper urinary tract and renal damage.

Comprehensive urologic care involves multifaceted urologic evaluation annually from the first year of life. It is possible, through various procedures described, to keep these children hygienic and socially acceptable. All children should maintain a high-fluid diet, and those without urinary diversion procedures should manually empty the bladder as completely as possible at regular predetermined time intervals.

Orthopedic and Habilitation Management of Patients with Spina Bifida and Myelomeningocele

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The orthopedic and habilitation management of patients with spina bifida and myelomeningocele is concerned with both the prevention and correction of deformities by surgical and nonsurgical means, and the utilization of assistive apparatus (wheelchair, braces, crutches, shoes) as substitutes for the loss in muscle power in order to attain, after a comprehensive program of treatment, the maximum functional potential.

The deformities that have been observed in our clinic, in patients with spina bifida and myelomeningocele, fall into two major categories.

Dynamic or muscle imbalance deformities are related to the level and extent of the neurosegmental lesion. These deformities are predictable. Table 2 presents the segmental innervation of the muscles in the lower extremity. It also indicates the functioning muscle groups crossing the joints of the lower extremity when each one of the neurosegments from L1 to S3 is preserved and the lesion affects the neurosegments below. Table 3 correlates the dynamic deformities to the neurosegmental levels of lesion.

Static or malposition deformities, in contradistinction to the dynamic deformities, are due to faulty position (lying, sitting, or standing) enforced by forces other than muscular (mainly by gravity). The static deformities are observed principally in high neurosegmental lesions (e.g., lesions from T6 to T10.) Table 4 summarizes the usual static deformities and their relation to the neurosegmental level of lesion.[2]

The different deformities observed in the patient with spina bifida and myelomeningocele could also be classified in relation to the involved body region as follows:

Spinal   Kyphosis, kyphoscoliosis, scoliosis, lordosis.

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Table 2. *Relationship of Muscle Activity to Neurosegmental Level of Lesion**

Neuro-Segmental Level	HIP	KNEE	ANKLE	FOOT	TOES
L - 1	WEAK FLEXION (Iliopsoas)				
L - 2	FLEXION (Iliopsoas and Sartorius) ADDUCTION (Adductor muscles)	WEAK EXTENSION (Quadriceps femoris)			
L - 3	FLEXION (Iliopsoas and Sartorius) ADDUCTION (Adductor muscles)	EXTENSION (Quadriceps femoris)			
L - 4	ABDUCTION (Tensor fasciae latae and Gluteus medius and maximus)	STRONG EXTENSION (Quadriceps femoris)	DORSI-FLEXION (Tibialis anticus)	INVERSION (Tibialis anticus)	
L - 5	EXTENSION (Gluteus maximus)	FLEXION (Medial hamstrings)	DORSI-FLEXION (Extensor digitorum communis and Extensor hallucis longus)	EVERSION (peroneal muscles)	
S - 1	EXTENSION (Gluteus maximus)	FLEXION (Lateral hamstrings)	PLANTAR-FLEXION (Triceps surae)	EVERSION (Peroneal muscles)	EXTENSION (Toe Extensor muscles)
S - 2	EXTENSION (Gluteus maximus)		PLANTAR-FLEXION (Triceps surae)		FLEXION (Long, Toe Flexors)
S - 3					(Toe Intrinsic muscles)

*This table indicates the functioning muscle groups present in the various joints of the lower limb when each of the neurosegmental levels from L1 to S3 is successively preserved. The quadruple segmental innervation of the muscles spanning the three major joints of the lower limb (hip, knee, ankle) is also represented in the table, by three heavily outlined rectangles, the juxtaposition of which gives a "staircase effect."

Hip	Dislocation, flexion abduction, flexion adduction, etc., with or without a rotary component.
Knee and leg	Genu valgum, rotary deformities of leg (internal or external rotation).
Foot	Calcaneus, calcaneovarus, equinus, equinovarus, cavus, and clawing of toes.

Spinal Deformities

The spinal deformities are caused by (1) intrinsic (spinal, suprapelvic) factors; namely, hemivertebrae, unsegmented vertebral bars, weakness in the spinal musculature, and deficiencies in the posterior ligamentous and osseous spinal elements; and (2) extrinsic (extraspinal, infrapelvic) factors; namely, flexion, abduction, or adduction deformities

Table 3. *Dynamic or Muscle Imbalance Deformities as Related to Neurosegmental Level of Lesion* *

LEVEL	SPINE	HIP	KNEE	LEG	ANKLE & FOOT
T-6 to T-12	KYPHOSIS SCOLIOSIS				·
L-1	SCOLIOSIS Asymmetrical hip flexor power	SUBLUXATION Weak hip flexors only muscles present			
L-2	SCOLIOSIS	EARLY DISLOCATION Strong unopposed Flexor-adductor power			
L-3	SCOLIOSIS	EARLY DISLOCATION Strong unopposed Flexor-adductor power	EXTENSION CONTRACTURE Quadriceps unopposed by Flexors		
L-4	SCOLIOSIS	LATE DISLOCATION Unopposed Flexors Adductors moderately opposed by Abductors	EXTENSION CONTRACTURE Quadriceps unopposed and stronger than at L-3	EXTERNAL ROTATION DEFORMITY Iliotibial band	CALCANEOVARUS Tibialis anticus unopposed by triceps surae and Peroneus longus muscles
L-5		SUBLUXATION Weak extensor muscles			CALCANEUS Foot dorsiflexors unopposed by Plantar flexors
S-1					CALCANEUS Weak Plantarflexors
S-2					CAVUS Lack of Intrinsic muscles

*The name of a deformity (capital letters) is underscored twice if it occurs frequently, once if occasionally, and not underscored if it occurs rarely.

about the hip joints, singly or in combination, affecting the spine secondarily and producing spinal deformities, mainly scoliosis.

Hip Deformities

The most important and perhaps one of the most disabling deformities in these patients is hip dislocation. This occurs rather early when L2 or L3 neurosegments are preserved and later when the L4 neuroseg-

Table 4. *Static or Malposition Deformities as Related to Neurosegmental Level of Lesion*

LEVEL	SPINE	HIP	KNEE	ANKLE & FOOT
T-6 to T-12	KYPHOSIS Lack of or insufficient power in trunk extensors. SCOLIOSIS: Asymmetrical hip FLEXION-ABDUCTION CONTRACTURE	FLEXION-ABDUCTION-EXTERNAL ROTATION DEFORMITY, Bilat. or FLEXION-ABDUCTION on one side and FLEXION-ADDUCTION on the other; SUBLUXATION, or DISLOCATION of the hip on the adducted side.	FLEXION DEFORMITY from sitting. GENU VALGUM on weight-bearing	Most frequently EQUINOVARUS (Tight heel cord and medial foot structures) Less frequently: CALCANEUS (Tight anterior foot structure)
L-1 to L-3	SCOLIOSIS: Asymmetrical hip FLEXION CONTRACTURE. LORDOSIS: Symmetrical hip FLEXION CONTRACTURE.	Same as above	Same as above FLEXION CONTRACTURE tendency at L-3 is diminished	Same as above
L-4 to L-5	Same as from L-1 to L-3	Less tendency to FLEXION DEFORMITY At the L-5 level		

ment is preserved and the ones below are absent. It is due to the un-balanced combined action of the hip flexor-adductor muscle groups. Dislocation occurs also following fixed adduction-flexion or abduction-flexion deformities about the hip, causing pelvic tilting. The pelvic brim on the adducted hip side rides higher. The head of the femur gradually dislocates. The leg on the side of adduction becomes shorter. The spine acquires a scoliotic deformity, an S-curve with the concavity of its lower segments facing the adducted hip.

Knee and Leg Deformities

The most frequent deformity in the knee, in high neurosegmental lesions, is genu valgum in weight-bearing position. The leg deformities are of the rotary type, either external (high lesions) or internal (with L2 and L3 neurosegments preserved). The internal rotation deformity is due to unopposed internal rotary action of the gracilis and sartorius muscles.

Foot Deformities

In the presence of high neurosegmental lesions, the usual foot deformity is equinovarus. In the low lesions, the deformity depends upon the level of lesion and the muscles present (e.g., when L4 neurosegment is preserved – with the anterior tibial acting alone in the foot – the foot deformity observed is calcaneovarus).

Treatment of Deformities

Our general philosophy in the management of deformities hinges on the early recognition of the particular nature of a deformity (dynamic or static) and its early treatment. Stretching, casting, and bracing, oftentimes successful in the management of static deformities, usually fail to correct dynamic deformities due to muscle imbalance. An impor-tant consideration in the latter type is the removal of a muscle from a location where it acts as a deforming factor and its relocation about a joint to anchor it in a position where the state of muscle force equilib-rium is obtained or approached.

Thus with L2 and L3 neurosegments preserved, early subluxation or dislocation of the hip cannot be effectively treated by stretching of adductor and flexor muscles or bracing of the lower extremities in a position of abduction and extension. The appropriate course of action under these circumstances is not only the diminution of the impact to the hip of the unopposed adductor-flexor forces, but also the creation of an antagonistic abductor-extensor force. This is obtained by the transfer of the iliopsoas muscle from the lesser into the posterolateral aspect of the greater trochanter through a window in the iliac wing. It cannot be overemphasized that, for a successful result with the least effort, the treatment must start at the earliest possible time.

Surgical management, when the conservative approach fails, con-sists of spinal fusion operations; soft tissue release operations about the pelvis, the hips, the knees, and the feet; osteotomies in the hip and the knee areas; arthrodesing operations in the foot; and muscle transfer

Table 5. *Suggested Surgical Correction of Foot in Spina Bifida According to Neurosegmental Level of Lesion, Type of Deformity, and Age*

LEVEL	TYPE OF DEFORMITY			RECOMMENDED SURGICAL PROCEDURE
L-3 and Above	FLAIL FOOT		EQUINUS	Segmental resection of heel cord. Posterior ankle capsulotomy.
			CALCANEUS	Segmental resection of anterior tendons (Tibialis anticus, Toe extensors). Anterior ankle capsulotomy.
	EQUINOVARUS with forefoot ADDUCTION			EQUINUS component corrected as above. Also, segmental resection of tight medial tendons (Tibialis posticus, Flexor hallucis longus and Flexor digitorum longus). Release of medial joint capsules; and, occasionally, in fixed forefoot ADDUCTUS, release of the dorsal, plantar, medial, and lateral tarsometatarsal joint capsules.
	PES VALGUS or PLANOVALGUS on weight-bearing			Subtalar arthrodesis between ages 4 and 8 years. Triple arthrodesis after 11 or 12 years old.
L-4	The above deformities may be observed			Treatment as above.
	In addition, due to activity of Tibialis anticus. Forefoot SUPINATION, CALCANEUS foot with VALGUS hind foot on weight-bearing. Occasionally, when the heel cord is also contracted, a ROCKER-BOTTOM DEFORMITY at the midtarsal joint is seen			Transference of Tibialis anticus to heel cord or segmental resection. After age 11 or 12, triple arthrodesis with appropriate wedge resection and/or transference of Tibialis anticus to heel cord or segmental resection.
L-5	All dorsiflexors are present and fairly well balanced: direct CALCANEUS DEFORMITY			Segmental resection of dorsiflexors, or transference to heel cord; and/or anterior ankle capsulotomy. Triple arthrodesis: at the appropriate age to correct any lateral foot imbalance.
S-1 and S 2	Foot may lack long toe flexors and/or intrinsic muscles. CAVUS foot deformity with CLAWING of toes.			Ankle fusion for anteroposterior ankle instability may be indicated. For mild CAVUS with CLAWING, use Jones procedure and/or Extensor digitorum communis transference. For severe PES CAVUS: triple arthrodesis with or without osteotomy of first metatarsal, plantar fasciotomy, and/or extensor transference.

operations in the hip and foot areas. A detailed listing of the different methods of correction of deformities of the spine, hip, knee, leg, and foot is out of place in a general outline of this type. Table 5 is included to suggest some of the methods employed in our clinic for the treatment of foot and ankle deformities.

Habilitation of the patients treated in our clinic starts as early as the child makes the first contact with the clinic personnel. The child is

Table 6.

Neurosegment Preserved	Prior to or during growth period	After growth period
L1 and above	Long leg brace, pelvic band or spinal attachment, limited ankle motion, ring lock at knee and hip. Crutches	Same
L2	Long leg braces, pelvic band, limited ankle motion, ring lock at knee. Crutches	Long leg brace, limited ankle motion, ring lock at knee. Crutches
L3	Long leg brace, pelvic band, limited ankle motion. Crutches	Short leg brace, limited ankle motion. Crutches
L4	Long leg brace, pelvic band, limited ankle motion. Crutches	Short leg brace, limited ankle motion. Crutches
L5	Long leg brace, limited ankle motion. Crutches	Short leg brace, limited ankle motion. May need one or two crutches.
S1	Long leg brace, limited ankle motion.	Short leg brace
S2	No apparatus	No apparatus
S3	No apparatus	No apparatus

Table 7. *Performance in Ambulation of 73 Spina Bifida Patients Grouped According to the Degree of Motor Deficit*

Performance in Ambulation of 73 Patients	Group I 18 Patients Age 4–26	Group II 18 Patients Age 4–17	Group III 5 Patients Age 4–17	Group IV 20 Patients Age 4–19	Group V 12 Patients Age 4–19
Independent without appliances				11	12
Independent with appliances					
Limited use of appliances Wheelchair required					
Not able to use appliances Wheelchair dependent or bedridden					

Table 8. *Performance in Activities of Daily Living of 73 Spina Bifida Patients Grouped According to the Degree of Motor Deficit*

Activities of Daily Living of 73 patients					Group V 12 Patients Age 4–
Independent without appliances					12
Independent with appliances					
Require assistance	1	1	1	1 & 12	

subjected to a thorough multidisciplinary evaluation. Goals are set for his motor performance based on the level of the neurosegmental lesion, deformities present in the trunk and the lower extremities, and results obtained at orthopedic surgery. A program is outlined and carried out for correction of deformity by stretching or splinting (e.g., Denis-Browne splint), maintenance of correction by splinting or bracing, increase of the muscle power and mobility of the joints to their useful range, and re-education and strengthening of transferred muscles. Table 6 correlates the needed assistive apparatus to the neurosegmental level of lesion.

To evaluate the ambulation performance (Table 7) and the performance in activities of daily living (Table 8), in a study of 73 patients, the following grouping was developed.[1]

GROUP I. No motor power is present in the lower extremities, but it is good in the trunk and above.

GROUP II. Motor power is present for hip flexion and adduction, and some knee extension may be present.

GROUP III. Motor power is present for hip flexion and adduction, knee extension, and dorsiflexion of the ankle.

GROUP IV. Motor power is good in the hip except for extension and abduction. Knee extension and flexion are good and there is some plantar flexion, eversion of the ankle, and movement of the toes.

GROUP V. Motor power is functionally normal in the lower extremities. There is some loss in the perineal area affecting sphincter control.

Summary

The deformities observed in patients with spina bifida and myelomeningocele and their orthopedic and habilitation management are

outlined. The results of performance in ambulation and in activities of daily living in a selected group of patients are given in tabular form.

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Neck and Shoulder Pain: Evaluation and Conservative Management

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The management of the patient with neck or shoulder pain is often difficult, largely because many questions as to exact etiologies are still unanswered. Conversely, the difficulty not infrequently lies in the failure of the physician to carry out an adequate examination of the patient to establish a correct diagnosis.

It is important to remember that pain in the shoulder does not necessarily mean that the cause is "intrinsic" since it may have an origin extrinsically distant to the joint itself.[15] The clinical picture may be straightforward, such as inflammation of the subacromial bursa; more often, however, the patient presents a mixed picture of symptoms, which without proper examination may lead to a vague diagnosis. Too often patients are told that they have a "cold in the shoulder," "pulled a muscle," "developed a bursitis or a tendonitis," only to find upon a later and proper examination that they have been suffering with a radiculitis from nerve root irritation at the cervical foramina. It is, therefore, essential that one develop a systematic way to approach the problem for proper diagnosis, for prescribing appropriate definitive therapy, and for effective results with the patient.

Although there are numerous and extensive classifications of the many causes of the painful shoulder,[5, 15] the simpler classification of Craig and Witt[6] is the most helpful in fixing sites of origin (Table 1).

A discussion of the mechanisms of pain referred from distant sites is outside the scope of this paper, except those related to conditions of the cervical spine. It is at times difficult to decide whether pain is originating in the shoulder itself or from pathology in the cervical spine or its related structures. Concomitant pain may often occur in both areas and be causally related.[10] Irritation or compression of the fifth cervical nerve root by osteophyte impingement on the C4-C5 foramen may, for example, produce some or no neck symptoms, but reflect severe pain to the muscles supplied by this root — rhomboids, deltoid, and biceps. This may

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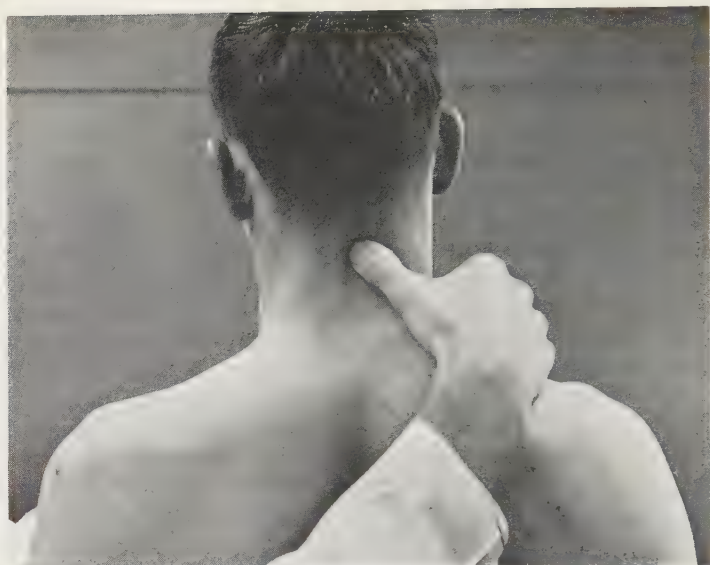
Figure 2.   Palpation of the posterior cervical spinous processes.

manifest in the presence of muscle spasm, of the trapezius, sterno-cleidomastoid, or paraspinal muscles for example, as well as in osteoarthritis. Abnormally excessive motion such as that secondary to ligamentous tear is usually not demonstrable clinically because of associated protective muscle spasm, but may be evident on x-rays taken with the neck in stress positions.

PALPATION OF THE POSTERIOR SPINOUS PROCESSES.   The posterior cervical spinous processes may be palpated with the spine in a slightly flexed position (Fig. 2). Radiation of pain into the shoulder girdle or arm resulting from forward pressure of the examiner's thumb on a posterior spinous process is suggestive of abnormal motion at that level with associated nerve root irritation.

PALPATION OF MUSCLES.   The muscles of the shoulder girdle and arm should be palpated for evidence of focal spasm and tenderness, so-called "trigger points." Palpation of these, if extremely sensitive, may reproduce referral of pain to other areas. Frequent sites of trigger points are in the upper trapezius, rhomboids, infraspinatous, deltoid origin and insertion, and in the long head of the biceps in the bicipital groove (Fig. 3).

PALPATION OF THE CERVICAL PLEXUS AND SCALENE MUSCLES.   The cervical roots and plexus can be palpated in the supraclavicular fossa as they emerge from between the scalene muscles and, also, high in the axilla. Palpation of the roots and plexus which produces pain radiating down the arm is strong evidence for radiculitis. The scalene muscles are also palpated for evidence of spasm or local tenderness.

HEAD AND SHOULDER COMPRESSION TESTS.   The examination should always include the application of pressure on the top of the patient's head

with the neck in a slightly extended and laterally flexed position; pain in the shoulder or arm elicited by this maneuver indicates nerve root irritation. Referred pain produced by downward pressure of the shoulder with the head rotated to the opposite side[10] similarly suggests a radicular origin.

INSPECTION AND PALPATION OF THE SUBACROMIAL BURSA.   Presence of local heat, swelling, and pain on palpation over the subacromial bursa are characteristics of acute bursitis or of either chronic or acute injury to the rotator cuff.

CODMAN'S JOG AND WINCE TEST.[2]   While applying downward pressure on the patient's abducted arm, a sudden release of pressure will produce a rebound upward impingement of the humeral greater tuberosity against the acromion process. If pain is produced in the shoulder by this maneuver, it is strongly suggestive of an inflamed bursa or a rotator cuff syndrome.

RANGE OF MOTION OF THE SHOULDER GIRDLE.   All ranges of motion should be measured and recorded accurately. These motions normally take place at the sternoclavicular, acromioclavicular, scapulothoracic and the glenohumeral joints, producing a smoothly integrated motion referred to as scapulohumeral rhythm.[9]

Motions at the glenohumeral joint consist of flexion, extension, internal and external rotation, adduction, abduction, and circumduction. With abduction and flexion of the glenohumeral joint, motion also occurs between the scapula and thorax and at the sternoclavicular and acromioclavicular joints.

Figure 3. Common sites of trigger points.

Motions of the scapula include elevation, depression, protraction, retraction, and rotation in both upward and downward planes.

Maneuvers for Neurovascular Compression Syndromes. Various maneuvers have been described to identify compression of the axillary vessels or brachial plexus due to tightness or spasm of the scalene muscles or to cervical ribs. While these maneuvers are helpful, they are not infallible[13] and results must be interpreted in context with other clinical signs and symptoms. For example, the diagnosis of claviculocostal syndrome would be suspect if one manually obliterated the radial pulse and then reduplicated the symptoms by bringing the shoulders back and down, actively by the patient, with additional passive pressure from the examiner.[1] However, this maneuver may obliterate the radial pulse in some patients who present no symptoms, thus being of no significance.

Examination should include careful grading and recording of the strength of muscles supplied by cranial nerves as well as those of the shoulder girdle and arm. Upper extremity reflexes and sensibility of the upper extremities should also be tested and noted. In the event of compression of a nerve root by a protruded cervical disc or a foramenal osteophyte, one would expect weakness in muscles supplied by that root, with possible loss of an appropriate tendon reflex, and a segmental sensory deficit.

Laboratory Tests, Electromyography, and X-Rays

Where needed, appropriate laboratory tests, electrodiagnostic procedures, and x-rays may aid in establishing a diagnosis. Electromyography, especially, may be extremely helpful in revealing early denervation and in the differentiation of a neuropathy from a myopathy. Nerve conduction studies, similarly, can be invaluable in the differentiation from as well as the localization of peripheral nerve entrapments; for example, they can be of acute importance in differentiating between a carpal tunnel syndrome and radicular cervical root pain when the sensory deficit in the hand and the rest of the extremity is equivocal or in instances in which pain is referred reversely into the forearm and shoulder from a median nerve compressed in the carpal tunnel.[14]

Appropriate x-rays of the cervical spine are often helpful diagnostically and should, in addition to the standard anteroposterior and lateral views, include oblique views to demonstrate possible foramenal pathology. In cases of cervical trauma, views of the odontoid process should also be obtained. In instances of intractable pain or of recurring episodes of neurologic symptoms, stress films in flexion and extension or cinéradiography may be helpful in identifying a site of instability or of abnormal motion. X-rays of the shoulder to demonstrate the possible presence of calcium deposits, local osteoporosis, osteoarthritis, or other pathology should be obtained in both internal and external rotation for greatest visualization.

TREATMENT

The aims of treatment are to (1) relieve pain, (2) reduce inflammation, (3) relax muscle spasm, (4) protect the injured part to allow

healing, (5) rebuild muscle power, and (6) restore normal ranges of motion and function.

Medications

ANALGESICS. Since many shoulder and neck problems are chronic and recurrent, dependency on narcotics should be avoided. Acetylsalicylic acid and associated compounds should be given on a regular basis in adequate dosage, e.g., 10 to 15 grains of ASA every 4 hours, as tolerated.

ANTI-INFLAMMATORY AGENTS. Phenylbutazone and indomethacin are often effective in reducing the acute inflammatory reaction of radiculitis or bursitis, if given in the recommended dosage and with due precautions. Short courses of oral steroids may be used providing the patient is otherwise medically suitable. Local injection of steroids into a bursa or around the bicipital tendon at times dramatically improves an acute inflammatory process.

MUSCLE RELAXANTS. The effectiveness of muscle relaxants on local muscle spasm is variable and controversial. An agent such as Diazepam in oral doses of 5 mg. four times daily may, however, be tried.

SEDATIVES, TRANQUILIZERS, AND MOOD ELEVATORS. The use of these depends largely upon the needs of the individual patient and the physician's judgment. Mild sedation during the daytime is important for patients with acute cervical injuries who are often extremely apprehensive and anxious.

ANESTHETICS. Injection of trigger point areas of local muscle spasm with procaine hydrochloride is frequently effective in relieving local pain and muscle spasm,[3] thus allowing a greater degree of mobility. Ethyl chloride spray may be similarly effective in relieving muscle spasm.

Physical Therapy

HEAT. The rationale for the use of local heat in muscle spasm and inflammatory conditions has been well established. By diminishing muscle spasm and reducing inflammation, it effects relief of pain and restoration of function. Moist hot packs (usually hydrocollator packs) applied for 20 to 30 minutes and hot baths or showers several times daily are more effective than dry heat.

Shortwave diathermy applied for 20 minutes to the cervical spine or shoulder provides somewhat deeper heating, but may have little advantage over the use of hydrocollator packs.[4] Ultrasound is also effective in heating deeper ligamentous and joint structures. Its dosage is based on the area to be covered and the depth of tissue to be heated and is prescribed in watts per square centimeter for a particular period of time. For tissues around the cervical spine and shoulder girdle, the dosage ranges from 0.8 to 1.5 watts per cm.^{2} for periods of 5 to 10 minutes. It is more useful in subacute rather than acute conditions; in the latter, it may aggravate and increase the pain. It has occasionally been useful in dispersing calcific deposits in the bursa and around the shoulder joint. The use of ultrasound and electrical stimulation in combination is often
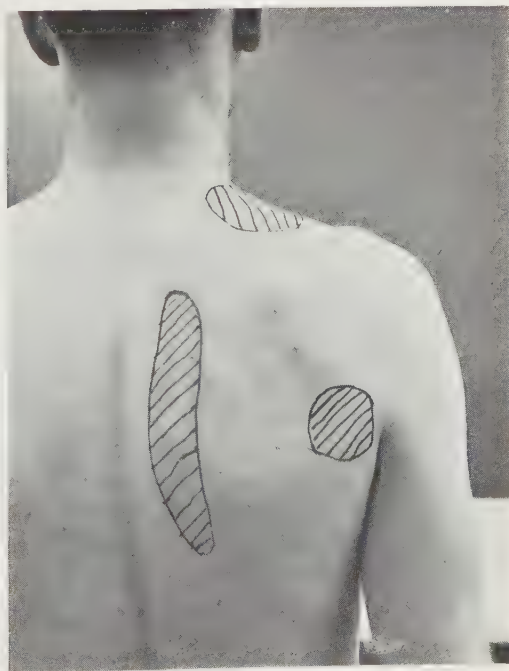
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effective in relieving local trigger point areas of muscle spasm by providing, in addition to heat, an alternating contraction and relaxation of muscle.

Cold. For some patients, particularly if acute, the application of cold may be more effective than heat in reducing muscle spasm and associated pain. Cold applied to the skin reduces local circulation, the local metabolic rate, as well as the rate of conduction of impulses by peripheral nerves. It can be applied in the form of cold packs for 15 to 20 minutes. Massaging of muscles with ice is another effective, safe and inexpensive way to employ cold in the management of neuromuscular problems.[16]

Massage. Massage is useful in relaxing muscle spasm and in improving blood flow. Too often, however, it is ordered as a substitute for more specific treatment. Since it is time-consuming for a therapist, and patients become fond of it quickly, it should be ordered only when specifically needed and then for a limited time only.

Exercise. For conditions of the cervical spine and shoulder a variety of types of exercises are useful. Local muscle spasm, such as in the trapezius, often responds to maximum contraction against resistance followed by relaxation. For limited ranges of motion and tight painful muscles at the shoulder, pendulum exercises are indicated. These must be done with the arm hanging loosely and the scapular muscles relaxed. As motion increases, they are executed with a weight in the hand, progressing to wall-climbing with the fingers and later to the use of a shoulder wheel. Passive motion, as a rule, is to be avoided, since the production of additional pain leads only to further muscle spasm with a decrease in motion. If there is muscle weakness, resistance exercises are indicated either with manual resistance by the therapist or by using weights.

For the treatment of an acute cervical torticollis without radicular signs, but with associated muscle spasm, self-traction exercise can be extremely effective. The patient is taught to pull his head upward with chin in, in an exaggerated military posture. Holding this position, he slowly rotates first to one side, then to the other. Slowly, all movements of the cervical spine are executed, usually with marked relief of muscle spasm and pain and restoration of motion.

Cervical Traction. Traction may be applied in a constant or intermittent form and in the vertical or horizontal position. The technique of traction used and the position of the patient depend upon the equipment available and the acuteness of the condition.

Constant traction produces some immobilization of the cervical spine and helps to relieve muscle spasm and pain. Correctly applied, it straightens the cervical spine and enlarges the intervertebral foramina to relieve compressive or irritative forces upon the nerve roots.[10]

Intermittent traction is increasing in popularity and, in some instances, is more effective in overcoming paracervical muscle spasm. It can be adjusted to the weight, period of traction, and period of relaxation desired. Traction and relaxation timing is in seconds and usually arbitrarily selected based upon clinical experience. During the traction

phase, the paracervical muscles tend to resist the forces of pull by contracting, while during the nontraction phase, they relax as the forces are reduced to zero. The result is a massage-like effect leading to reduced muscle spasm and more effective subsequent traction. Due to its relaxation phase, intermittent traction permits the application of greater weights with less discomfort. The application of a hydrocollator cervical pack preceding or during either form of traction augments muscle relaxation.

There is no uniform agreement as to the amount of weight required to produce distraction of vertebrae.[11, 12] Vertical traction, however, with 5 to 10 pounds, as is often used, is inadequate as it does little more than support the head. For vertical traction, Jackson[10] advocates beginning with 15 to 20 pounds and gradually increasing to 35 to 50 pounds in more muscular individuals. It should be applied for 15 to 30 minutes daily or a minimum of three times weekly. The forces must be applied to the occiput and not to the mandible, and, in most instances, with the head held in 10 to 15 degrees of flexion (Fig. 4). Not only is this position better tolerated by the patient, but it more readily produces the desired effect on the posterior vertebral structures. The patient sits facing the unit at a distance of 1 to 2 feet, so that the angle of pull is approximately 60 degrees to the horizontal. Pressure on the mandible can be avoided and the desired angle of pull accomplished by using an adjustable head halter.

Horizontal traction is most commonly used for the acute hospitalized patient. It has the advantages of permitting prolonged traction with the patient in a more relaxed position, but since the traction time is longer,

Figure 4. Motorized intermittent vertical cervical traction.

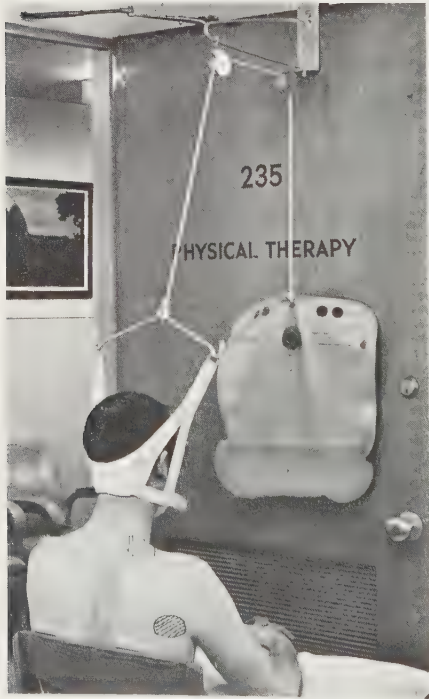Figure 5.   Constant horizontal cervical traction.

Figure 6.   Door home traction unit with water bag.

weight tolerance is less. Patients are usually started with 5 pounds for 1 to 2 hours three times daily and slowly increased as tolerated to 8 or 10 pounds for most of the day and night with rest periods at mealtime. Since in most instances the desired objective is the same as with vertical traction, it is important that the angle of pull, usually one of slight flexion, be properly adjusted and maintained. Too commonly, patients in horizontal traction experience bitter discomfort and frequently an increase in symptoms because the traction is applied at an improper angle, which forces the patient's neck into extension, thus transmitting most of the force to the mandible. Other causes of discomfort are poorly fitting head halters and excessive traction weight. To correctly attain traction forces at the occiput and to relieve forces on the mandible, the pulley should be elevated so that the line of pull is directed upward and backward at an angle of approximately 45 degrees to the horizontal (Fig. 5).

Once traction has been found helpful to the patient, it may be useful to teach him how to apply it at home on a maintenance basis. A simple home unit such as that in Figure 6 attaches to a door and is used with a water bag or weights.

Orthotic Devices

CERVICAL COLLARS. Cervical collars are used to maintain some immobilization of the cervical spine to reduce mechanical stress on its joints and ligaments. Inflammatory reactions tend more rapidly to subside, strained or torn ligaments to heal, and painful muscle spasms to relax. The type of collar used depends largely on the degree of immobilization required. If it is used mainly as a reminder to the patient not to move his neck in extreme ranges of motion, then a soft foam collar will suffice. For firmer immobilization, a plastic, molded leather or felt wrap-around collar may be used, with or without the addition of a chin plate or occipital plate. To achieve maximal immobilization, a four-poster collar, plaster jacket, or molded fiberglass jacket will be necessary.

For most conditions of the cervical spine it is desirable to support the neck in neutral position with the head tilted slightly forward.[10] Motions to be limited are usually extension and extremes of rotation. A collar, therefore, should provide adequate support under the occiput to prevent extension, and where limited rotation is desired, a chin plate is added. Unfortunately, a large number of commercially available collars force the neck into hyperextension, primarily limiting flexion while providing little occipital support.

The edges of the collar should be padded sufficiently to prevent pressure discomfort, and certain anatomical landmarks should be observed for proper fitting. Posteriorly, its superior aspect should fit under the occiput below the superior nuchal line; if it rests against the occipital protuberance, pressure discomfort will develop. The inferior border should rest on the trapezeii without pressing on the lower cervical or upper thoracic spinous processes. Anteriorly, the superior edge should be shaped to prevent pressure on the mandibular angles and, if a chin plate is used, pressure should be widely distributed and not focused just

Figure 7.   Cervical ruffs.

on the mental protuberance. Inferiorly, the collar should be cut out over the clavicles to permit pressure to be borne on the manubrium. Patients should be advised to expect some initial discomfort and possible skin irritation until they have become adapted to the collar.

Simple cervical ruffs (Fig. 7) are quite effective in providing partial immobilization of the neck and limitation of extension. These are made of cotton surgical padding placed inside 1 inch stockinette, leaving 6 to 8 inches of stockinette in front for ties. They can be cheaply and quickly made and are extremely comfortable. Two ruffs are usually adequate; their widths may be varied by adding layers of cotton inside the stockinette. They effectively limit neck motion during sleep, and are usually well tolerated in contrast to plastic and metal collars which do not lend themselves to comfort in bed.

SLINGS.   Slings are helpful in providing support and rest for an acutely painful shoulder. Many types are used, from the familiar, simple Red Cross cloth sling to the more complicated, sophisticated ones with leather cuffs. When a sling is used, it is important to remember that the extremity must be removed from it at least once daily for gentle active exercise to preserve ranges of motion.

Case History

Mrs. S., a 46 year old housewife, was referred by her family physician for consultation with a diagnosis of a right "shoulder bursitis." She had experienced pain in the right shoulder for approximately 6 months without relief from several local injections of cortisone and only temporary relief after a 3 week course of phenylbutazone. On close inquiry, she described periods of neck stiffness for

about 2 years, usually on arising in the morning, with difficulty in turning her head to the left. Also, the shoulder pain occasionally radiated to the medial border of the right scapula and down the arm to the region of the common extensor origin in the forearm. She also experienced a tingling sensation in the right thumb and index finger. Other medical history was noncontributory except that she had been in a car accident 8 years ago with no apparent injuries.

Examination revealed motion of the cervical spine to be limited in rotation bilaterally because of pain in the lower neck. Forward pressure by the examiner's thumb on the sixth cervical posterior spinous process caused pain to radiate to the right shoulder. Marked local tenderness was noted on palpation of the cervical nerve roots in the right supraclavicular fossa and pain radiated down the right arm to the forearm. Tenderness was also noted on palpation of the right rhomboid muscles, at the insertion of the deltoid muscle, and on rolling the right bicipital tendon with the examiner's fingers. Range of motion of the right shoulder was limited in flexion and abduction by 30 degrees and internal rotation by 40 degrees. No muscle weakness was noted, and reflexes and sensation were within normal limits.

X-rays of the cervical spine revealed osteophyte encroachment on the right C5-C6 intervertebral foramen. X-rays of the right shoulder were unremarkable.

The diagnosis of cervical osteoarthritis with a right C6 radiculitis was made.

The patient was started on a program of physical therapy consisting of moist heat in the form of hydrocollator packs to the neck and right shoulder for 20 minutes, followed by ultrasound in combination with electrical stimulation to the muscles of the right shoulder girdle at a dosage of 1.5 watts/cm.² for 10 minutes. This was then followed by intermittent vertical cervical traction, with the patient positioned so that the angle of pull was approximately 60 degrees to the horizontal and with a force of 25 pounds. The traction phase was set at 10 seconds and the relaxation phase at 10 seconds for a period of 15 minutes. Treatment was carried out three times weekly, with the traction force slowly increased to 40 pounds. In addition, the patient was taught a program of active shoulder exercises to be done at home after applying heat to the neck and shoulder. After an initial period of slightly increased pain, her symptoms slowly subsided and after a total of 12 treatments, the pain had completely disappeared with complete restoration of shoulder function. Initially the patient was advised to wear a cervical collar, but she rejected the idea for cosmetic reasons.

SUMMARY

This paper deals with a systematic approach to the evaluation of neck and shoulder pain and a discussion of available conservative methods of treatment. Since many causes of shoulder pain originate outside the shoulder itself, a meaningful diagnosis can only be established after careful history taking and adequate physical examination. The important points in history taking and physical examination have been outlined. Treatment consists of various medications, physical therapy and orthotic devices. Stress has been placed on the various physical therapeutic modalities and the proper application of cervical traction. Several types of collars have been described with emphasis on proper fitting to ensure adequate immobilization and comfort. The paper is concluded by presentation of a typical case history.

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Evaluation and Medical Management of Low Back Pain

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There are few practitioners of clinical medicine who are not faced at one time or another with a patient complaining of low back pain. Both lay and medical writers in the past few years have presented more and more statistics supporting the impression that the incidence of low back problems is high and continually increasing. The National Safety Council estimates that injuries of the back causing time lost from work exceed 500,000 a year and cost employers about one billion dollars in sick pay to incapacitated workers and in wages for their replacements.

It is realized, of course, that the increase in the number of patients who consult physicians for low back complaints—as for many other complaints—is a reflection to some extent of the greater accessibility of medical opinion and treatment to more people. Beyond that factor, however, the ever-increasing luxuries and ease of living have led to less and less actual use of muscles with resultant deconditioning and loss of proper interplay of the muscles, particularly those of the trunk and lower extremities. This deconditioning, in turn, makes the back more susceptible to stress and results in painful derangement.

There is a considerable degree of pessimism about the success of treatment for low back derangement in the lay press, among patients suffering from the problem, and even in the minds of many medical practitioners. This degree of pessimism is not warranted—provided that the physician takes the time to understand the anatomic and physiologic mechanisms of the back and then applies this understanding to an accurate evaluation of the patient's symptoms and signs and, ultimately, to proper treatment.

ANATOMIC CONSIDERATIONS

The anatomy of the back usually seems perplexingly complex to the freshman medical student and often remains so to the medical practitioner throughout his clinical career. In order to approach the problem of low back pain with any degree of success it is essential that the ana-

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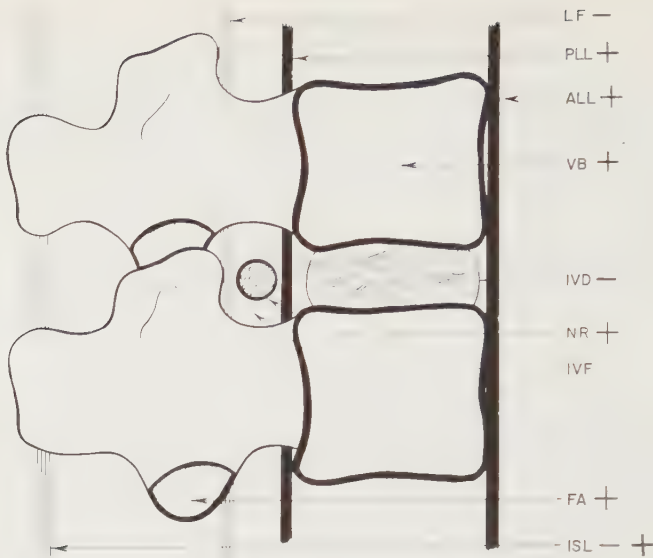
Figure 1. The functional unit of the spine.[1] ALL, Anterior longitudinal ligament; FA, facet articular cartilage; ISL, interspinous ligament; IVD, annulus fibrosus of intervertebral disc; IVF, intervertebral foramen containing nerve root (NR); LF, ligamentum flavum; PLL, posterior longitudinal ligament. +, Pain-sensitive; − nonsensitive. (Reproduced with modification by permission of the author and publisher.)

tomic complexity of the back be unraveled. The designation of certain structures as the functional unit of the spine is a useful concept in understanding the origin of pain in the low back (Fig. 1). This functional unit is composed of two adjacent vertebrae with their articulations, an intervening disc, ligaments, and nerve roots. Intimately related to the functional unit are the spinal muscles. Certain tissues are sensitive to pain (that is, they contain sensory nerve endings) and others are not. The pain-sensitive tissues are the anterior longitudinal ligament, the posterior longitudinal ligament, the vertebral body, the synovium and capsule of the intervertebral joints, the nerve root, and the muscles.[1,2] The interspinous ligament may also contain pain fibers,[1,3] but it is relatively insensitive compared to other structures.

The muscles of the back, which often seem impossibly complex, can be greatly simplified by dividing them into two groups—the short muscles, which involve only one functional unit (that is, they extend from one vertebra to an adjacent vertebra), and the long muscles, which cross a number of such units. Specifically, the following are the short muscles: (1) spinalis, connecting two adjoining spinous processes; (2) transversalis, joining two adjacent transverse processes; and (3) multifidus, originating from a spinous process and attaching to a transverse process of the adjacent vertebra below. For the purposes of this discussion it will suffice to remember only that there are several muscles which join each functional unit and which function to stabilize their own particular unit or segment. By binding together adjoining vertebrae the short muscles

and the ligaments stabilize individual segments of the spine, thus enabling the long muscles to move a number of segments as a group.

In the position of normal stance there are three curves in the spinal column—a cervical lordosis, a thoracic kyphosis, and a lumbar lordosis. By means of these curves, balance is achieved and the weight of the trunk is centered over its base, as delineated by the feet. As long as balance is achieved, the erect position can be maintained without muscular effort. The ligaments act mainly as check reins to prevent excessive motion. The cervical and lumbar lordotic curves are functional and can be reduced, reversed, or increased by muscular action or by gravity. The thoracic kyphotic curve is relatively fixed.

Motion in the lumbar spine is confined largely to flexion and extension. Upon forward flexion, lumbar lordosis is reduced, and upon extension it is accentuated. Lateral inclination is possible only to a moderate degree. Rotation occurs mainly at the thoracolumbar junction.

When the spine functions properly in a static and kinetic manner, there should be no pain. The presence of pain indicates irritation of sensitive tissue in or near the spine. Such irritation is the result of dysfunction of the spine in either its static or its kinetic state.

It has been the author's experience that in the majority of patients — perhaps 75 per cent—pain resulting from static dysfunction of the spine is associated with an increase in the lumbosacral angle with a consequent increase in lumbar lordosis. An increase in the lumbosacral angle (that is, the angle formed by the superior border of the sacrum with the horizontal) and the accompanying increase in lumbar lordosis result in a greater shearing stress between the lumbar vertebrae, with the maximal increase occurring between the fifth lumbar and first sacral vertebrae. The increased lumbar lordosis produces pain. The degree of lordosis, or extension of the spine, is limited by the anterior longitudinal ligament, which may become painful when overstretched. Hyperextension of the lumbar spine results in narrowing of the posterior disc spaces and approximation of the posterior components of the vertebrae. These posterior articulations thus assume weight-bearing—a function for which they were not intended. When this approximation occurs, the joint surfaces are compressed and painful synovial inflammation may result. Hyperextension, by approximating the posterior vertebral segments, can mechanically irritate the nerve root as it emerges through the intervertebral foramen. This irritation can take place even in the presence of a normal disc, but, of course, is much more likely in the presence of a narrowed or herniating disc.

One of the most commonly observed examples of low back pain resulting from increased lumbar lordosis is that experienced by women in the third trimester of pregnancy. The increased anterior weight of the pregnant uterus necessitates increased extension or lordosis of the lumbar spine in order to keep the weight of the trunk over its base.

Kinetic pain implies irritation of pain-sensitive tissues initiated by movements of the spine. Cailliet's[1] classification of the etiology of kinetic pain is useful in evaluating the patient with derangement of the low back. (1) Abnormal stress on a normal back. This type of stress

occurs, for example, when a person with a normal back catches a falling weight of several hundred pounds. (2) Normal stress on an abnormal back. This category is self-explanatory. The abnormality may, for example, be a structural defect of the vertebral column or weakness of muscles. (3) Normal stress on an unprepared normal back. An example of this type of stress is the lifting of a heavy load when it is expected to be a light load such as a full suitcase that is thought to be empty.

CLINICAL EVALUATION

History

A carefully elicited history, of course, is a sine qua non in the establishment of any diagnosis. In the case of low back pain it is of more than usual importance, often contributing considerably more insight into the diagnosis than the physical examination. Perhaps more than with any other symptom an accurate, detailed description of pain is difficult to elicit. Even the best patient-historian may be too vague and general in describing his pain. The physician must pursue the history of pain with much prodding and perseverance, if he is to make the most of the patient's symptoms.

Certainly one must obtain a general appraisal of the patient—age, sex, economic and social background, occupation, social habits (including sports), general health, and past illnesses and injuries. These factors may not only offer a clue to the purely physical aspects of the patient's symptomatology, but also provide a measuring stick, so to speak, of such factors as the patient's threshold of pain, reaction to stress, and willingness to cooperate with treatment.

As for the pain itself, every aspect must be explored historically. The onset of pain must be established. When and where did it begin? Was the onset associated with trauma or illness? Often a patient will date the onset to a fairly recent episode, forgetting or neglecting to mention that his very first episode of pain occurred 10 or 20 years ago. The course of the pain is important, both in establishing a diagnosis and in predicting response to treatment. Has the pain improved, worsened, or remained the same since its onset? Is the pain intermittent or steady? The site of the pain must be determined. Where was the pain at its onset? Has it changed in location? Is the pain confined to the back or does it radiate? If it radiates down the lower extremity, along which aspect of the limb does it radiate and how far distally does it extend? When it is difficult for the patient to localize the pain accurately with words, he may be able to be more specific by pointing to the site of the pain.

Patients' descriptions of the quality of pain vary widely. The quality of the pain, as described by the patient, often depends upon the patient's previous experience with pain and may not be very valuable to the physician's analysis of the pain. The interpretation of the severity of pain by the patient is also quite variable. The description may be vague and inconsistent. Useful indexes to the degree of severity include inability to work, inability to engage in social activities, confinement to bed, and interference with sleep.

It is essential to determine what factors, if any, make the pain better or worse. Is the pain precipitated or aggravated by coughing or sneezing? How does position influence the pain? Characteristically, the patient having pain associated with degenerative disc disease, as well as with certain other causes, does not tolerate sitting well and much prefers a reclining position or even standing and walking. The patient with instability of the low back, as in spondylolisthesis, may be quite comfortable at rest in any position, even sitting, and experiences pain or sensory disturbance only with motion. It is important to question the patient about sensory changes as well as pain. Is there paresthesia down either or both lower extremities? The same factors that affect pain must be determined in regard to sensory changes. Finally, one must determine what previous treatment, if any, the patient has received and what effect, good or bad, the treatment has had upon his low back symptoms.

Physical Examination

Once a careful history has been elicited, the patient must be examined thoroughly and methodically. It should go without saying that the patient must be undressed so that the entire back and lower extremities can be inspected and palpated. In the presence of acute symptoms it may not be possible to perform a complete examination initially. A general appraisal of the patient's physical characteristics and mannerisms must be made. Many of the aspects can be observed as the patient enters the physician's office and while the history is being taken.

Once the patient is undressed, inspection of the patient's posture is quite revealing. The entire spine must be inspected and palpated for the presence, or absence, of a true scoliosis or a lateral bend secondary to acute derangement of the back. Increased lumbar lordosis should be noted. Or there may be flattening of the lumbar curve as a result of muscular spasm in the presence of acute pain. An increase in lumbar lordosis is often accompanied by rounding of the shoulders, forward thrust of the head, and protuberance of the abdomen. The presence or absence of a lateral tilt of the pelvis should be noted. A discrepancy between the height of the right and left iliac crests may reflect a true shortening of one leg or may be the result of an apparent shortening secondary to contracture of a joint or a deformity in the lower extremity. Either type of shortening, real or apparent, may contribute to low back pain. While the level of the pelvis is being inspected, the patient should be checked for a positive Trendelenburg sign on either side.

The degree of mobility of the spine must be evaluated in flexion, in extension, and in rotation to either side. Limitation of motion may be due to pain and muscular spasm, to chronic tightening of muscles and ligaments, or merely to fear of producing pain by movement. With the patient still standing, the presence or absence of tenderness and muscular spasm must be determined by palpation. It is helpful to have the patient flex forward over the examining table to provide greater separation of the spinous processes of the vertebrae and allow tenderness over the intervertebral disc spaces to be elicited more easily.

The degree of passive straight leg raising possible with the patient supine on the examining table must be determined. Straight leg raising

may be limited by sciatic nerve root irritation, muscular pain and spasm in the low back, or tight hamstrings. An increase in pain with abrupt, passive dorsiflexion of the ankle superimposed upon straight leg raising further substantiates the impression that it is irritation of the sciatic nerve which limits straight leg raising.

Various maneuvers of the hips should be carried out — both to reveal contractures, especially of the hip flexors, which may be contributing to the derangement of the low back, and also to help determine whether the hip joint is the site of pain rather than the low back. These maneuvers should include passive motion of the hip joint in each direction, combined passive abduction, flexion, and external rotation, and combined adduction and internal rotation, the latter two combinations to reveal pathology in the hip joint or in the capsule and ligaments of the hip.

Certainly a careful neurologic examination must be conducted to determine the presence or absence of motor weakness, sensory loss, or abnormal reflexes.

When an extruded disc or other mass resulting in radicular compression is suspected, a positive Naffziger's test (precipitation or aggravation of pain or sensory disturbance over the distribution of the involved root upon manual compression of the jugular veins bilaterally) offers confirmatory evidence of such a lesion. A negative test is less significant.

Every patient, male or female, with low back pain deserves a rectal examination to rule out prostatic disease or a rectal or extrarectal mass. The rectal examination also permits palpation of the coccyx, which may be contributing to the pain. The skin should be inspected carefully for café-au-lait spots in order to point to the possibility of neurofibroma.

Diagnostic Studies

Certain laboratory studies may be helpful in establishing a diagnosis. A complete blood count, erythrocyte sedimentation rate, uric acid, alkaline phosphatase, and acid phosphatase should be obtained as indicated by the physician's clinical judgment. X-rays of the lumbosacral spine are helpful, both by exclusion and by inclusion of abnormal findings. If x-rays are worth taking, they are worth taking well and should include anteroposterior, lateral, and right and left oblique views, and a spot-film of the lumbosacral junction. If the history and physical findings suggest instability of the lumbosacral spine, additional lateral views with the spine in flexion and in hyperextension should be obtained. Such bending films may reveal malalignment of the vertebrae that is not present on a lateral film in the normal standing position.

Electromyography, by revealing electrical potentials of denervation or nerve root irritation, can be useful in determining the number and level of nerve roots involved in compressive lesions. In many cases the clinical picture is sufficiently clear that the confirmatory evidence offered by electromyography is unnecessary for the establishment of a diagnosis. In some cases, however, it is quite helpful in establishing the involvement of multiple root levels as opposed to compression of a single root by a herniated disc, in differentiating a degenerative disease, such as amyotrophic lateral sclerosis, from disc disease, and in evaluating the

paresis or paralysis that is suspected to be due to hysteria or malingering.

When the patient has not responded to an adequate course of conservative management and when compression of nerve roots, cauda equina, or spinal cord is suspected, a myelogram with Pantopaque is indicated. Myelography is useful in determining the presence and level of herniated discs, in differentiating herniated discs from tumors, and in detecting partial and complete blocks resulting from osteophytes or spondylolisthesis. Myelography should only be considered as a prelude to surgery; it is not a routine diagnostic test when surgical intervention is not being strongly considered.

Armed with an accurate history, a careful physical examination, and appropriate laboratory tests, the physician is in a position to diagnose the etiology of the patient's low back symptoms. The most common causes of low back pain are herniated disc, degenerative arthritis, and muscular strain. The classic disc syndrome with sciatic pain, muscular spasm in the back and even in the lower extremities, positive straight leg raising, and possibly neurologic deficits in one or both lower extremities, is easy to recognize. However, even with this complex of findings, one must be alert to the possibility of other causes, such as an intraspinal tumor, an intrapelvic tumor, or a tumor in the buttock or thigh. The absence of back pain, the absence of intolerance for sitting, or failure to obtain some relief from lying down (except with a very acute disc syndrome) should heighten the physician's suspicion of a diagnosis other than a herniated disc. Spondylolisthesis may also produce the findings of a classic disc syndrome, although the symptoms and signs in the lower extremities resulting from spondylolisthesis frequently are intermittent rather than persistent. Roentgenograms of the lumbosacral spine should aid in the diagnosis or elimination of spondylolisthesis.

Other causes of low back pain may not be as easy to differentiate. The symptoms of muscular or ligamentous strain, degenerative arthritis, osteoporosis, metastatic lesions of vertebrae, rheumatoid spondylitis, and early discogenic disease may be quite similar. Certain features of the history are helpful in differentiating these diseases. A precipitating factor of trauma may direct one's suspicion toward muscular or ligamentous strain or early discogenic disease. A history of frequent recurrence of pain in the low back, with or without trauma, should put the physician on the alert for the eventual development of a full-blown herniated disc.

The age of the patient may be helpful in directing suspicion toward certain diagnoses. Certainly one should suspect osteoporosis in the postmenopausal female, possibly in combination with degenerative arthritis. The young man—and sometimes the young woman—with rheumatoid spondylitis may escape accurate diagnosis for years, frequently being labeled with a diagnosis such as chronic or recurrent lumbosacral strain, fibromyositis, or even idiopathic sciatica. The onset is insidious in the majority of cases and is usually associated with symptoms referable to the low back. The early complaints usually consist of episodes of aching and stiffness, transient low back pain, or sciatica. Only a high degree of suspicion will lead the physician to make

an accurate diagnosis by ferreting out the details of the history and obtaining confirmatory diagnostic tests. The only laboratory test of value in rheumatoid spondylitis is the erythrocyte sedimentation rate, which is elevated in approximately 80 per cent of cases, but may be normal in mild, but nevertheless active, cases.[3] Roentgenographic findings are quite characteristic. Changes in the sacroiliac joints are diagnostically the most helpful and are usually the earliest roentgenographic findings in rheumatoid spondylitis.

TREATMENT

Once a diagnosis of mechanical derangement has been made on the basis of a proper history, physical examination, and appropriate laboratory studies, treatment can be instituted. Treatment is described in this discussion in a progressive manner from the acute to the chronic phase. The patient can be started on the appropriate phase of treatment, depending on the acuteness or chronicity of his problem. Obviously, the treatment at any phase should be modified to the needs of the individual patient.

Acute Phase

Rest in bed is of prime importance in the treatment of an acutely painful low back, because it eliminates the stress of gravity and painful muscular spasm. A patient with an acutely deranged back should lie on a firm mattress with a bedboard between the mattress and springs. Proper positioning is of great importance and often provides dramatic relief from pain. For most painful backs the semi-Fowler position with the hips and knees supported in flexion is the position of choice.

Traction is usually helpful. By placing a patient in a semi-Fowler position and then applying traction properly, as indicated in Figure 2, it is possible to tilt the pelvis anteriorly and flatten the lumbar curve, thereby opening the posterior aspects of the vertebrae.

Heat is beneficial in the presence of significant muscular spasm. In addition to relaxing spastic muscles, heat usually has a mild, generally sedative effect on the patient. When available, moist heat, as delivered by Hydrocollator packs, is generally the most comfortable for the patient, although diathermy is sometimes preferred. It is important to keep the patient in a flexed semi-Fowler position during the administration of heat, either on his back or in a side-lying position. If the pain is mild enough to permit transportation of the patient by stretcher, immersion in a warm Hubbard tank is often beneficial.

In the early acute stage, massage may be painful and is therefore contraindicated. However, later it is a useful adjunct in relaxing muscular spasm and diminishing pain.

Certain medications should be used to give relief from pain during the acute phase. Analgesics are often necessary. The simpler ones should be tried first, but it may be necessary in the presence of severe pain to resort to narcotics. Several of the muscle-relaxing drugs may be helpful in combating painful muscular spasm. Most of the muscle relaxants in
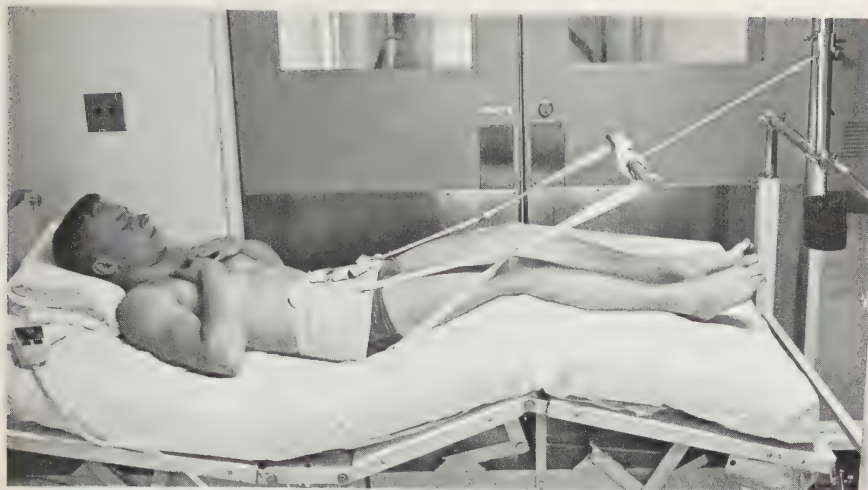
Figure 2.   Correct application of pelvic traction with the patient in a semi-Fowler position. The pelvic band, by means of which traction is exerted, must fit snugly above and on the iliac crests. The lateral bands, extending from the pelvic band to the spreader bar, must pull at an angle that tilts the pelvis (that is, rotates the symphysis pubis superiorly).

use at the present time also have the desirable effect of sedating or tranquilizing the patient, thereby decreasing psychic tension and facilitating the patient's relaxation. In some cases an anti-inflammatory agent such as phenylbutazone, indomethacin, or even adrenal corticosteroids, may, by reducing the edema of inflammation, give considerable, even dramatic, relief.

After a period of bed rest, with or without traction, when there is evidence of both subjective and objective improvement, ambulation may

Figure 3.   Instructions to patient for exercise 1: Press your lower back down into the table by tightening your buttocks and abdominal muscles. Next tuck your chin in so as to flatten the back of your neck against the table. Hold this total position for a slow count of five. Do not hold your breath. To relax, slowly release in this order: the neck and shoulders, abdomen, and buttocks.

Figure 4.   Instructions for exercise 2: Repeat exercise 1 to the hold position. Bend right knee to the chest, grasp knee in both hands, and draw knee firmly towards the chest. Tuck chin in and attempt to place forehead on knee. Hold for a count of five. Slowly return first the neck to the starting position and then the knee. Now relax as in exercise 1. Repeat, using the left knee.

be gradually resumed. In the case of an acute herniated disc, bed rest for 2 to 3 weeks or even longer may be required. If the first attempts to stand and walk for 5 to 10 minutes at a time are tolerated well, the time is progressively increased. Sitting is tolerated less well than standing and walking, and should be restricted to brief periods of time.

Figure 5.   Instructions for exercise 3: Repeat exercise 1 to the hold position. Bend right knee to the chest, grasp knee in both hands, and draw knee firmly to the chest. Slide left heel down until left leg is flattened against the table. Keep left knee straight with back of knee pressed firmly against table and pull foot upward toward shin. Hold for a count of five. Slowly slide the left heel back to starting position and replace right knee. Relax as in exercise 1. Repeat with the left knee.

The use of a corset has several purposes. First, it permits earlier ambulation and resumption of normal activities, although it is not needed in every case. A second purpose for using a corset is to restrict motion in those derangements in which instability of vertebral segments is the predominant factor in producing pain.

It is important to understand what a corset can do. A corset does not eliminate the stress of gravity; it does restrict mobility of the spine. In the presence of muscular spasm, the purpose of which is to immobilize the spine, the corset provides the immobilization and thus eliminates the need for painful spasm. The major benefit of bracing must be assumed to be the positioning and maintenance of the spine in proper physiologic curves. For this reason the proper molding of the corset is of the utmost importance. The corset should insure maintenance of a flattened lumbar curve – that is, elimination or minimization of lumbar lordosis.

The garment should be long with the upper border at the lower portion of the rib cage and the lower border at the inferior crease of the buttocks. The average adult usually requires a garment 16 inches in length. A shorter corset does not splint; it can, in fact, increase lumbar lordosis by pressing in upon the midportion of the lumbar spine. Posteriorly the corset should have rigid steel stays that extend the full length of the garment. These stays should be flat through the lumbar

Figure 6. Instructions for exercise 4: Repeat exercise 1 to the hold position. Straighten right knee and pull right foot upward toward right shin. Raise right leg toward your head. When it is raised as far as possible without bending the knee, hold for a count of five and then bring it down to starting position. Relax as in exercise 1. Repeat, using left leg.

Figure 7.   Instructions for exercise 5: Repeat exercise 1 to the hold position. Have some-one press down on your ankles or feet or secure feet under edge of couch or other furniture. With both arms reaching forward, tuck in the chin and slowly curl up into a sitting position. Hold for a count of five. Uncurl by allowing the mid-back to reach the floor first, followed by shoulders, neck, and head. Relax as in exercise 1.

area with merely enough posterior convexity in their lower portions to accommodate the contour of the buttocks. The stays of the corset should determine the curvature of the spine and not vice versa.

In the author's experience back braces usually offer little advantage over corsets and have the disadvantage of being less comfortable than corsets for most patients. Discomfort means that the patient frequently will not wear the brace or, if he does, will fight it by contracting his trunk muscles in such a way as to push or squirm away from the un-comfortable pressure point, thus defeating the purpose of the brace. Occasionally a brace is preferable to a corset – for example, in a man who does fairly heavy work and who, rightly or wrongly, requests a brace rather than a corset because he thinks he would feel more secure in a more substantial looking support. In certain cases a specific brace, such as a Williams flexion brace, which has a more dynamic effect on posi-tioning of the spine, may be preferable to a corset.

A serious mistake is often made with bracing or supporting the spine. Many times a patient is given a corset which permits him to func-tion comfortably and is sent on his way – without exercises. The corset makes it possible for the patient to maintain proper posture without muscular effort. In a surprisingly short time the muscles of the trunk become deconditioned and then are totally incapable of supporting the spine properly when the patient attempts to go without the corset. In most patients it should be possible to eliminate a corset eventually. The

patient should be weaned away from the corset before it becomes impossible to do so.

Subacute or Chronic Phase

The patient has actually reached the subacute phase by the time he is ready to be up and about in a gradually progressive manner with or without a corset. This is the point at which a great mistake is made so often in the management of low back disease – treatment is stopped. It is not enough merely to alleviate the pain with the measures just described and then pronounce the patient well and fit to return to full activity. The underlying pathomechanics must be treated. In fact, the purpose of the early treatment is merely to relieve pain so that the real treatment can be carried out later. The real treatment is the correction or, at least, the alteration of the underlying pathomechanics and the restoration of proper interplay of muscles, which can be accomplished

Figure 8. *Left*, Before starting the exercise. *Right*, At the peak of the exercise. Instructions to patient for exercise 6: Stand with back against the frame of a doorway. Place heels 4 inches away from the frame. Flatten low back into frame of door, allowing your knees to bend a little. Tuck chin in and attempt to flatten or press the neck against the frame. For counterbalance press both hands against the opposite side of the frame. Straighten both knees. At this point your entire trunk is pressing against the door frame. Hold for a count of five and then relax.

only by instituting a carefully supervised program of graduated exercises.

Careful supervision is of the utmost importance and means that the patient must be taught the proper exercises, as prescribed by his physician, in a series of sessions with a physical therapist. It is naive to think that most patients can be taught a few simple exercises in one or two sessions and then the problem is solved. And certainly it is not effective to give a patient a written list of exercises and merely tell him to go home and do them. The overwhelming majority of patients with complaints of chronic low back symptoms or recurrent episodes of acute symptoms seen by the author have never been given any exercises at all, or have been given improper exercises, or have been given proper exercises with insufficient supervision or instruction.

The exercises illustrated in Figures 3 to 8 have been carefully designed to preserve or restore the mechanically desirable alignment of the spine and pelvis and the proper interplay of action of the muscles and ligaments of the back. These six basic exercises are aimed at correction of the mechanical faults which most commonly contribute to painful derangement of the low back. Many of the principles involved are observed in a number of exercise regimens for the low back. However, certain of the exercises in the well-recognized regimens of low back exercises have subtle faults that result either in insufficient reconditioning of the muscles or in some cases even in enhancement of the pathomechanics.

These exercises are useful therapeutically for the majority of faulty backs and prophylactically for the majority of asymptomatic backs. However, it must be realized that some backs will need a modification of this program because of the presence of mechanical abnormalities which differ from those which occur most frequently. This difference must be recognized by the physician and prescribed for accordingly.

The mere performance of a few exercises each day without regard for proper alignment of the spine and interplay of muscles in all activities of daily living will do little to correct the patient's low back problem. In addition to being trained to do proper exercises, the patient must be educated to incorporate the proper mechanical principles into sitting, standing, walking, moving—actually into everything he does.

In Exercise 1 (Fig. 3) the pelvic tilt is the basic exercise for proper mechanics of the low back and is the first step in all of the subsequent exercises. In this exercise, with the patient lying in the supine position and the hips and knees flexed with the feet flat on the table, the pelvis is tilted so that the symphysis pubis is rotated superiorly and the lumbar spine is flattened against the table. The extensors of the neck and back, the gluteal muscles, and the abdominal muscles are maximally contracted isometrically. The patient is cautioned to keep his chin tucked in and is instructed not to push against the table with his feet. He must also be reminded to keep breathing throughout the exercise.

Almost without exception the pelvic tilt is a desirable exercise for low backs since it decreases the lumbar lordosis. On rare occasions, discomfort in the low back is enhanced by flattening the lumbar lordotic

curve. This effect is usually predictable or explainable, if the patient's history, physical examination and roentgenograms are carefully evaluated.

Exercise 2 (Fig. 4) is designed to stretch out tight extensor muscles and other soft tissues of the back and hips. Exercise 3 (Fig. 5) stretches out tight hip flexors and heel cords. Exercise 4 calls for straight leg raising to stretch out tight hamstring muscles (Fig. 6). Frequently the stretching of very tight hamstring muscles can be facilitated by first contracting the hamstring muscles maximally just before attempting maximal straight raising of the leg. In the presence of an inflamed sciatic nerve, as with a recently acute herniated disc, care must be taken not to irritate the nerve further in an attempt to stretch the hamstring muscles. Exercise 5 is a sit-up to provide maximal strengthening of the abdominal muscles (Fig. 7). Exercise 6 repeats all of the maneuvers of the first exercise, but is performed in an upright, weight-bearing position (Fig. 8). The purpose of this final exercise is to teach the patient proper posture for standing and walking.

The therapist must make sure that the patient begins each exercise with the basic pelvic tilt and isometric contraction of muscles of the trunk. This maneuver is the keystone for the success of the entire regimen of exercises. It should also be noted that at all times during the non–weight-bearing exercises the lumbosacral spine and pelvis are stabilized and, thereby, protected from hyperextension by keeping one hip and knee flexed with the foot flat on the table or floor.

Once the patient has become proficient in the performance of his exercises, he is then instructed to continue the exercises daily at home for an indefinite period of time. The physician must assume the responsibility of following the patient at appropriate intervals and of advising him in progressive resumption – or avoidance – of normal activities.

SUMMARY

The problem of low back derangement appears to be increasing. The conservative management of the patient with low back pain can be effected with considerable success by the physician who understands the normal and abnormal anatomic and physiologic principles of the back and then applies this understanding to his evaluation of the patient and ultimately to treatment based on these principles.

Once an accurate appraisal, based on history, physical examination, and laboratory studies has been made, proper treatment can be instituted. During the acute phase therapeutic measures are directed toward relief of pain. However, to consider treatment complete merely with relief of pain is inadequate. Once discomfort has been eliminated or significantly reduced, then the stage is set for the most important aspect of treatment – the correction of the reversible pathomechanics of the lumbosacral spine and the restoration of proper interplay of the muscles. These objectives can be accomplished only by a carefully supervised program of exercises and re-education of the patient to assume mechanically desirable posture and movement in all activities.

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Complications in the Rehabilitation of Hemiplegic Patients

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The rehabilitation of the hemiplegic patient has been discussed extensively in the literature during the past few years. Various techniques and training procedures have been developed and adapted in most community hospitals as part of the total management of the stroke patient. Effective liaison has been established between the physiatrist, the neurologist, and the internist to insure early mobilization and prompt discharge of the patient following a cerebral vascular accident (CVA).

The recovery of function in the hemiplegic patient (HP) following a CVA depends on the extent of the cerebral infarction[12] and the development of superimposed complications during the early and late convalescent phases of the illness. At times, it is difficult to distinguish between the hemiplegic manifestations and insidious complications which obscure and often delay recovery of function. Prompt recognition and treatment of these problems may contribute toward a more complete restoration of function, compatible with the degree of cerebral dysfunction. Continuity of care following discharge of the HP to the community or custodial facility is essential in order to prevent the regression of function achieved during the active rehabilitation program. The long-term follow-up of such patients on a maintenance basis[7] enables the physician to recognize late complications, primarily of a musculoskeletal nature, which eventually contribute to the gradual deterioration of the hemiplegic patient.

A comprehensive evaluation of the HP should include a survey of the various interrelated factors which contribute to his physical and mental performance. A systemic appraisal is necessary in order to develop a baseline for future reference in assessing the improvement or regression of the patient, thereby alerting the physician to the presence

Table 1.   PULSES Profile*

P   *Physical* condition including diseases of the viscera (cardiovascular, pulmonary, gastrointestinal, urologic, and endocrine) and cerebral disorders which are not enumerated in the lettered categories below.
    1. No gross abnormalities considering the age of the individual.
    2. Minor abnormalities not requiring frequent medical or nursing supervision.
    3. Moderately severe abnormalities requiring frequent medical or nursing supervision yet still permitting ambulation.
    4. Severe abnormalities requiring constant medical or nursing supervision confining individual to bed or wheelchair.

U.   *Upper* extremities including shoulder girdle, cervical and upper dorsal spine.
    1. No gross abnormalities considering the age of the individual.
    2. Minor abnormalities with fairly good range of motion and function.
    3. Moderately severe abnormalities but permitting the performance of daily needs to a limited extent.
    4. Severe abnormalities requiring constant nursing care.

L.   *Lower* extremities including the pelvis, lower dorsal and lumbosacral spine.
    1. No gross abnormalities considering the age of the individual.
    2. Minor abnormalities with fairly good range of motion and function.
    3. Moderately severe abnormalities permitting limited ambulation.
    4. Severe abnormalities confining the individual to bed or wheelchair.

S.   *Sensory* components relating to speech, vision, and hearing.
    1. No gross abnormalities considering the age of the individual.
    2. Minor deviations insufficient to cause any appreciable functional impairment.
    3. Moderate deviations sufficient to cause appreciable function impairment.
    4. Severe deviations causing complete loss of hearing, vision, or speech.

E.   *Excretory* function, that is, bowel and bladder control.
    1. Complete control.
    2. Occasional stress incontinence or nocturia.
    3. Periodic bowel and bladder incontinence or retention alternating with control.
    4. Total incontinence, either bowel or bladder.

S.   *Mental* and *Emotional Status.*
    1. No deviations considering the age of the individual.
    2. Minor deviations in mood, temperament and personality not impairing environmental adjustment.
    3. Moderately severe variations requiring some supervision.
    4. Severe variations requiring complete supervision.

PROFILE

P	U	L	S	E	S

*From Moskowitz, E. and McCann, C.: Classification of disability in the chronically ill and aging. *J. Chronic Dis.*, 5:342-346, 1957.

of superimposed complications. The PULSES profile, adapted from the Canadian and American military classification systems, has been used by the author for such an appraisal of function (Table 1). It will serve as the topical outline for the ensuing discussion of complications in the hemiplegic patient.

PHYSICAL CONDITION (P)

This category of the profile includes the various medical and surgical complications which can adversely affect the rehabilitation of the HP. Although it is recognized that the CVA is usually a complication of an underlying cardiovascular disease, the latter plays a secondary role in a discussion of the HP, as do other medical problems, such as diabetes and diseases of the other viscera. Too frequently the reverse is true: major emphasis is on the treatment of the underlying medical problems, with too little regard for the simultaneous management of the hemiplegia.

Hypertensive cardiovascular disease is a frequent "complication" in hemiplegic patients and may be initially detected at the onset of the stroke. Mobilization of such a patient must proceed with caution when there is evidence of subarachnoid bleeding, such as nuchal rigidity and bloody or xanthochromic spinal fluid. Rehabilitation procedures should be withheld in such patients until the extent of the CVA has been assessed and the condition of the patient has been stabilized. On the other hand, early rehabilitative measures should be instituted in those patients with long-standing hypertensive cardiovascular disease without evidence of subarachnoid bleeding. Not infrequently, vigorous treatment with antihypertensive drugs produces a physiologic hypotension in such patients and prevents any effective mobilization, due to severe lassitude which deters them from standing or even sitting in a wheelchair. It has been demonstrated that hypertensive hemiplegic patients are able to fully participate in a rehabilitation program under appropriate medical supervision. In a small series, it has been observed by this writer that such patients demonstrate a small decrease in systolic blood pressure after moderate effort, obviously reflecting a degree of cardiac insufficiency.

Similar problems arise when there is evidence of myocardial insufficiency or recent infarction, particularly when noted on routine electrocardiograms. Practical experience has demonstrated that such ECG changes should be evaluated with considerable leeway, particularly in the elderly patient. One must consider the alternatives – to maintain the hemiplegic patient at absolute bed rest, or to proceed with the physical restoration program under close clinical observation. An episode of acute myocardial insufficiency rarely occurs during any form of physical or occupational therapy, for the simple reason that these patients are observed closely and their physical activity is graded to their capacity. As a matter of fact, most hemiplegic patients in a rehabilitation setting usually have another CVA or a myocardial infarction during the night or weekend when there is no scheduled treatment. This phenomenon has been amply documented and requires no further elaboration in this paper.

Adequate control of an associated diabetes is self-evident, but one must consider the variability of the dietary intake of the patient in prescribing hypoglycemic drugs. This is particularly true in patients with pseudobulbar palsy, who cannot chew or swallow their food. Others are unable to cut their food or feed themselves when their dominant

hand is affected. This poses a serious problem during evening and weekend meals, when staff shortages in the average hospital find the aphasic stroke patient left to his own resources in the seclusion of his private room. In such instances, the family should be taught simple bedside techniques and permitted to attend and help the patient feed himself, to prevent hypoglycemic episodes.

Dehydration of the HP is the frequent result of these feeding difficulties. The problem is further complicated by the use of sedatives and tranquilizing drugs in restless elderly patients. They usually have a reversal of their sleeping habits, so that they are drowsy during the day, preventing any effective rehabilitation activities, and noisy during the night. The patient is unable to eat or drink, yet the routine medication is continued and further dehydration ensues, with elevated blood urea nitrogen and higher drug concentrations in the blood. The patient becomes semistuporous and the diagnosis of another CVA is entertained. Hydration of such patients and the elimination of all sedative drugs produces a prompt and dramatic remission.

Malnutrition, secondary to pseudobulbar palsy, in the HP who has had one or more strokes with protracted recovery, requires painstaking care. It is time-consuming and is beset with the hazards of aspiration. In isolated instances, such a patient can best be managed with a gastrostomy and elimination of nasogastric tube feeding. One can then more closely observe the patient for any return of the swallowing and gag reflex. If there is any return of function as manifest by the ability of the patient to manage small amounts of semisolid food, he can be gradually tried on oral feeding supplements; if successful, the gastrostomy can be clamped and gradually closed.

The patient with pulmonary emphysema and fibrosis is managed as the case with myocardial insufficiency. Extensive laboratory studies are not essential, since they do not give any practical answer to the question as to how much physical activity the hemiplegic patient with emphysema can tolerate. As in nonhemiplegic patients with emphysema, clinical observation with gradual increase of physical effort will usually result in increased exercise tolerance.

UPPER EXTREMITIES (U)

During the early phase of rehabilitation of the HP it is often difficult to distinguish between symptoms and clinical findings resulting from the CVA and those secondary to superimposed complications. This is particularly true in the case of the paralytic upper extremity.

A semiconscious or stuporous patient is apt to develop a variety of root or nerve compression lesions due to a malposition while lying immobile in bed.[8] This is equally true of the patient under anesthesia, under the influence of alcohol, or following a CVA. The situation is further compounded in the case of the HP by the fact that the arm is plegic, making it more vulnerable to compression by lying usually at the side of or under the patient. These traction or pressure neuropathies may involve the cervical roots, the brachial plexus, or the peripheral

nerves, giving rise to a variety of atypical clinical findings which masquerade as components of the hemiplegia.

For instance, Erb's palsy affecting the C5-C6 roots will produce paralysis of the deltoid and biceps muscles, often in the presence of active function in the distal segments. Sensory changes may be present if the lesion is more severe and involves an area of decreased sensation localized over the lateral aspect of the shoulder. The biceps reflex is diminished or absent. Segmental atrophy involving exclusively the deltoid and biceps muscles follows. The lower motor neuron findings are in sharp contrast to the upper motor neuron signs in the remainder of the limb, such as increased deep tendon reflexes in the forearm and triceps muscles and spasticity and a positive Hoffmann's sign in the fingers. Sensation may be intact in the remainder of the limb. This paradox of upper and lower motor neuron findings should lead one to suspect a superimposed neuropathy, which can be confirmed by electro-myographic studies. This is not an academic problem, since such neuropathies may give rise to irreversible contractures if not treated and splinted adequately. For instance, in Erb's palsy, the patient may have recovery of hand function but remain with a disabling frozen shoulder.

The long thoracic nerve may be involved when the arm is permitted to dangle between the side rails of the bed, with pressure against the scapula. This causes a paralysis of the serratus anterior muscle, producing a "wing scapula" and impaired elevation of the arm. Lesions of the median and ulnar nerves produce profound weakness in the hand (Fig. 1) despite fairly good recovery from the hemiplegia. Compression of the ulnar nerve may also occur as a late complication, and results from pressure over the ulnar groove at the elbow while the patient sits in a wheelchair (Fig. 2).

The drop wrist resulting from a radial nerve palsy is difficult to distinguish from that of the hemiplegia; however, the absence of wrist

Figure 1. Median and ulnar neuropathy associated with hemiplegia.

Figure 2.   Ulnar neuropathy caused by prolonged pressure over the elbow in a hemiplegic patient confined to a wheelchair. (From Moskowitz, E., and Porter, J. I.: Peripheral nerve lesions in the upper extremity in hemiplegic patients. New Eng. J. Med., 269:776-778, 1963, reproduced with permission.)

extension in the presence of active opposition of the thumb should lead one to suspect such a condition and confirm it by electromyography. The situation is further complicated in the diabetic patient where one has to rule out the possibility of a metabolic neuropathy. In such instances, evaluation of the normal upper extremity is essential.

The Shoulder

Frequent reference has been made in the literature to the "painful hemiplegic shoulder," as though it were a specific clinical syndrome or entity. Given a cross-section of the nonstroke population averaging the same age, one would encounter an appreciable incidence of shoulder pain for varying reasons. To these causes must be added several other specific factors incidental to the CVA, which can lead to a painful shoulder.

Reference has already been made to paralysis of the deltoid muscle secondary to a peripheral nerve lesion, which causes a painful, contracted shoulder. Trauma to the shoulder is frequently overlooked, particularly when it is incurred at the time of the CVA by a fall on the paralytic side. The patient can sustain an impacted fracture of the surgical neck of the humerus. Fortunately, the management of this fracture in the older patient consists of early mobilization of the shoulder to prevent the subsequent development of a stiff joint.

Trauma from a fall, or repeated small traction injuries to the paralytic shoulder while the patient is in bed, may produce lesions of the rotator cuff or biceps tendon with the attendant symptoms of pain and limitation of motion. Treatment consists mainly of gentle assisted exercises in the supine position. Locally, the tender area may be needled with

hydrocortisone. The application of diathermy should be avoided, particularly if the patient has a loss of skin sensation. Pulley exercises are beneficial during the later stages, once the patient has become more cooperative and ambulatory.

During the flaccid stage of the hemiplegia, the weight of the arm tends to distract the shoulder capsule, causing a diastasis (not dislocation) of the shoulder joint. The traction of the arm may then produce shoulder pain when the patient is standing or sitting. The use of a simple sling is indicated when the patient is walking, to prevent the distraction; however, it is better to prop the arm on a pillow, with the shoulder in some abduction, when the patient is sitting. This will avoid the constant use of the sling, which only increases the tendency to the development of the typical adduction–internal rotation contracture of the shoulder.

Pain in the shoulder may be due simply to the development of a contracture secondary to the hemiplegia. This can be avoided by early mobilization with active and passive exercises. If instituted early and properly administered, contractures can be avoided.

In some instances, the HP will continue to have progressive loss of motion with increased pain, despite recovery of function. These patients are usually emotionally unstable and depressed, and are often difficult to manage. In addition, they may also develop similar complaints referable to the hand, manifest by pain and limitation of motion. This symptom complex is now an incipient hand-shoulder syndrome, more appropriately termed posthemiplegic reflex sympathetic dystrophy.[9] The cause of this condition remains obscure, just as it does in

Figure 3. Extensive spotty demineralization of the shoulder joint in a hemiplegic patient with reflex sympathetic dystrophy. (From Moskowitz, E., et al.: Posthemiplegic reflex sympathetic dystrophy. J.A.M.A., 167:836-838, 1958, reproduced with permission.)

Figure 4. Heterotopic ossification of the shoulder in a hemiplegic patient.

patients following myocardial infarction or after trauma to the upper extremity. It occurs in about 5 per cent of stroke patients in the experience of this author, provided that every painful shoulder or hand is not classified as a dystrophy. In severe cases, there is noted the characteristic spotty (rather than diffuse) demineralization of the head and neck of the humerus and adjacent glenoid process of the scapula, as illustrated in the radiograph in Figure 3. This condition must be treated intensively in order to prevent the rather disastrous, irreversible contracture of the shoulder. Local infiltration of the shoulder with hydrocortisone has no effect. Oral phenylbutazone or corticosteroids are effective when prescribed during the early evolution of this disability and combined with vigorous active and passive exercises. The management of the dystrophic hand is discussed in another part of this paper.

Lastly, one can encounter the stiff, totally immobile and completely paralytic painful shoulder. Fortunately, this is a rare complication. Manipulation will lead only to further disability and increased pain. X-ray examination of the shoulder will reveal extensive calcification and even ossification involving the periarticular structures, particularly on the adductor or medial side of the glenohumeral joint, as illustrated in Figure 4. This heterotopic calcification produces a complete fusion of the shoulder by an extra-articular bridge of bone. Obviously, any manipu-

lation will only cause further trauma and increased ossification. In the absence of any active function in the extremity, surgical intervention could hardly be justified.

The Elbow

From the preceding discussion, it is apparent that any deviation from the typical hemiplegic attitude of the upper extremity should lead one to suspect the presence of a superimposed complication which may be impeding functional recovery or causing additional discomfort to the patient. The elbow tends to assume a flexed position, which is due to the earlier recovery of function of the biceps and brachioradialis muscles and the predominant flexor spasticity which supervenes. In slightly less than 1 per cent of the cases of hemiplegia following a CVA, one may encounter a patient with an extension, rather than flexion, contracture of the elbow, even in the absence of extensor spasticity. Flexion is severely restricted and painful. Initially, there may be some warmth about the elbow, suggesting the possibility of arthritis. Failure to respond to antirheumatic drugs including colchicine should suggest the possibility of an incipient heterotopic calcification,[10] provided that local infection including thrombophlebitis has been ruled out. Prompt immobilization of the elbow in flexion is essential and all manipulation is to be avoided. Radiographic examination in the lateral view will reveal a small nidus of heterotopic calcification overlying the olecranon process. This distinct calcific shadow should not be confused with a hypertrophic spur which is contiguous with the olecranon process at the insertion of the triceps tendon. Assisted exercises without stretching should be gradually reinstituted as soon as the local reaction and pain subside.

Thrombophlebitis of the hemiplegic upper extremity may be overlooked, particularly when the paretic limb is used for intravenous feedings and immobilized on an arm board when the patient is restless. Extension of the elbow is usually restricted and there is deep tenderness over the biceps muscle and in the antecubital fossa. Associated vasospastic phenomena in the forearm and hand should lead one to suspect a deep thrombophlebitis involving the brachial vein. The restraint must be released and the use of the arm for intravenous feeding discontinued. Hot compresses should be applied with caution if there is loss of sensation associated with the hemiplegia. The forearm and hand should be elevated, avoiding extreme flexion in the elbow. The use of anticoagulants should be undertaken with caution and due regard for the cause of the CVA. Gentle assistive exercises are resumed as soon as the swelling and tenderness subside to prevent the development of contractures particularly in the shoulder and fingers. The patient should be provided with a lapboard to support the arm while sitting in a wheelchair, to prevent the dependent edema which usually follows such an episode. Elastic compression bandages are ineffective since they only tend to promote additional swelling of the dorsum of the hand and the fingers.

Hyperflexion in the elbow secondary to severe spasticity is a troublesome late complication which can be difficult to manage. Vigorous

stretching may lead to repeated minor tears in the brachialis muscle, ultimately causing the formation of a myositis ossificans in the antecubital fossa (in contrast to the heterotopic calcification on the extensor side). More recently, motor nerve[1] and motor point[2] blocking with dilute solutions of phenol has proved effective in releasing the flexor spasticity. Repeated injections may be necessary if the spasticity recurs or has been inadequately relieved.

The Hand

Function in the plegic hand following a CVA may be adversely affected by the complications that have been described in the proximal segments of the limb. The complexity of function coupled with the multiplicity of joints makes the hand most susceptible to contractures and deformities. Impaired sensory function including astereognosis creates additional problems and frustrations for the patient. Direct trauma, particularly burns, may be unnoticed; severe flexor spasticity in the wrist and fingers may create hygienic problems in the care of the hand. The skin in the palm of the hand may become macerated by long uncut fingernails. These are some of the problems encountered in the spastic hand of the HP.

Other complications have already been described, including peripheral nerve lesions and persistent swelling with edema secondary to thrombophlebitis, or simply due to dependency. In reflex dystrophy, the hand and fingers are puffy but not edematous and the skin temperature is increased during the early phase of the development of the syndrome. The metacarpophalangeal joints are extended and the thumb is not adducted and flexed across the palm as in the typical spastic hand. The normal joint contours are obliterated and trophic changes are apparent in the skin. Passive and active flexion of the metacarpophalangeal joints is painful and strongly resisted. The application of the traditional platform splint for the hemiplegic hand compounds the problem by promoting further stiffness and disuse. The x-ray changes are similar to those described in the shoulder, namely, extensive spotty demineralization primarily involving the carpal bones and the distal ends of the radius and ulna.

Prompt recognition and treatment of this complication is essential in order to prevent irreversible contractures and permanent disability. This is particularly significant when latent recovery of function in the hand is obscured by the superimposed complication. As in the case of the shoulder, oral medication with corticosteroids or phenylbutazone combined with vigorous active and passive exercises should be instituted. Paraffin baths may be of some value, provided the wax is applied with the fingers in maximum flexion at the metacarpophalangeal joints. Elastic bandages and splints should be avoided. If there is no improvement or the condition deteriorates, prompt blocking of the stellate ganglion is indicated, followed immediately by passive mobilization of the fingers. This should be repeated until definite improvement has been achieved.

Splinting of the spastic hand with the characteristic thumb-in-palm attitude has been most unsatisfactory. Elaborate supports have been

Figure 5. Thumb splint for the spastic hemiplegic hand.

developed but are discarded by the patient promptly after discharge from the hospital or rehabilitation center. They are cumbersome, difficult for the patient and family to apply, and usually do not afford any additional function. In the experience of the author, the splint illustrated in Figure 5 has proved the most acceptable to the patient since it can be applied without any assistance. It is a simple splint which maintains the thumb in abduction-extension and thereby facilitates the release of flexor spasticity in the fingers (Temple Fay phenomenon).

Blocking of the motor nerves and motor points of the extrinsic flexor muscles of the wrist and fingers with dilute phenol solutions is being employed with increasing success as the technique is refined but the results are not always permanent. If the wrist is contracted in a hyperflexed attitude, surgical release of the flexor tendons at the medial epicondyle followed by passive extension of the wrist to the neutral position may afford some cosmetic improvement.

LOWER EXTREMITIES (L)

Recovery of function in the lower extremity usually precedes that in the upper, so that complications are more apt to be recognized. The added factor of weight-bearing makes it imperative that complications

be avoided wherever possible and treated energetically to prevent any delay in the ambulation of the patient.

Pain in the thigh referred to the knee joint, particularly when moving the paretic limb in bed or during physical therapy, may be the first indication of a hip fracture sustained at the onset of the CVA. It may be associated with an impacted fracture of the surgical neck of the humerus. Shortening of the limb may not be present if the transcervical fracture is impacted. Definitive treatment should not be delayed unless the patient is critically ill in order that convalescence from the fracture of the hip may proceed concurrently with recovery from the stroke.

The Hip

Fracture of the hip is also a late complication and invariably affects the paretic extremity. If the patient has been ambulatory, immediate surgical intervention is indicated to avoid the unnecessary and disastrous effect of immobilization with traction. Replacement of the head with a prosthesis, followed by immediate ambulation with full weight-bearing, has become the accepted procedure in fractures of the neck of the femur in the elderly hemiplegic patient. In the author's experience simple pinning of the fracture after closed reduction, followed by progressive weight-bearing as tolerated by the patient, is a less traumatic procedure with a lower mortality rate and less postoperative morbidity.[11] It is recognized that early weight-bearing after hip pinning is unorthodox, but one must consider the alternatives—the higher morbidity with the replacement procedure or the catastrophic effect of a bed and wheelchair existence until the fracture has healed (this carries more than a 30 per cent possibility of nonunion).

Adductor spasticity of the hip creates a serious problem in ambulation and is one of the major factors responsible for hip fracture in the HP. When such a patient sustains a hip fracture the surgeon should be requested to relieve the adductor spasticity by simple tenotomy at the time of the reduction of the fracture. Postoperatively, the patient may walk with a more stable gait than prior to the injury. In other cases with progressive adductor spasticity associated with a deterioration of gait, blocking of the obturator nerve with a short-acting anesthetic, followed immediately by ambulation, will afford the physician an evaluation of the extent of the problem as influenced by the spastic adductor muscles, rather than by a disturbance in proprioception. A satisfactory response to the diagnostic block can then be followed by an adductor tenotomy. Recently, motor point blocking of the muscles with dilute phenol has been shown to give similar results, with varying degrees of success. Section of the obturator nerve is a major procedure which is not justified in most cases.

An adduction-flexion contracture of the hip with or without spasticity may be due to underlying osteoarthritis or Paget's disease, which usually involves both hip joints. Ambulation of the hemiplegic patient with this disability poses a serious problem because of the inability of the pelvis to accommodate to the paretic extremity. It may be necessary to build up the shoe on the affected side rather than on the uninvolved

Figure 6.   Posthemiplegic heterotopic ossification of the hip joint.

leg as is customarily done to permit the patient to clear the foot without a scuff.

Lastly, adduction-flexion deformity of the hip may be due to extensive heterotopic calcification involving the periarticular structures, as illustrated in Figure 6. Fortunately, this usually occurs in rare instances, in the debilitated patient who has been bedridden for a protracted period. Treatment is futile.

The Circulation and Nerves

Vascular complications occur more frequently in the hemiplegic lower extremity than in the upper. It must be emphasized that sitting or reclining in a chair is not the equivalent of early ambulation. As a matter of fact, it may be more disastrous than bed rest, particularly when the leg is in extreme flexion at the hip and knee and the foot dangles with the toes touching the floor. Similarly, maintaining the patient in the traditional orthodox anatomic alignment in bed without frequent changes of position serves no purpose other than to promote circulatory stasis and decubiti.

Thrombophlebitis occurs in about 10 per cent of the stroke patients during the period immediately following the CVA. The duration of immobilization should be as brief as possible. The author has not been

impressed by the effect of anticoagulants in shortening the period of recovery from thrombophlebitis. As a matter of fact, it occurs in stroke patients who have been on anticoagulant therapy. Phenylbutazone, moist compresses, and elevation of the leg usually bring prompt relief. When the patient is reactivated, the leg should be wrapped in soft cotton bandages (similar to those used to line a cast) and covered completely, except for the toes, with elastic bandages, which should be removed when the patient returns to bed, to prevent the formation of ridges on the skin.

An incipient occlusion of the femoral artery may masquerade as thrombophlebitis. Evaluation may be difficult, particularly if the patient is aphasic. Circulatory changes may have been present prior to the development of the condition. Pain in the lower limb is usually unremittant. There may be evidence of an ischemic neuropathy manifest by changes in motor and sensory function, particularly involving the deep branch of the peroneal nerve, which is most sensitive to arterial insufficiency. The foot drop may become more pronounced, deep tendon reflexes may be lost and a segmental sensory deficit involving the dorsum of the foot, especially the first web space, may herald the onset of a major arterial occlusion. The progressive skin changes make surgical intervention imperative.

One must also consider other neuropathies, just as the upper extremity. Prolonged pressure over the sciatic notch in a debilitated patient may cause a sciatic neuropathy producing a compound neurologic deficit with upper and lower motor neuron changes. Likewise, pressure over the head of the fibula will cause the classic peroneal nerve palsy with complete foot drop. Nerve conduction velocity studies may help differentiate between a sciatic and peroneal nerve palsy. Flaccidity in the calf muscles and an absent ankle jerk is definite evidence of sciatic rather than peroneal nerve involvement. The prognosis for recovery from the lower motor lesion is good if recognized early and the pressure is relieved. Pressure over the anesthetic areas must be avoided to prevent the formation of trophic ulcers. Well-fitted, comfortable, flexible shoes should be provided and an appropriate brace prescribed when indicated. Active and passive exercises are prescribed to prevent contractures, especially of the calf muscles.

The Knee

The knee joint of the HP is subjected to considerable stress during ambulation, particularly in the presence of spasticity in the quadriceps and calf muscles associated with weakness in the hamstrings. Many of these patients also require a short leg brace to stabilize the foot and ankle. They tend to develop a relaxation of the supporting structures, particularly the cruciate ligaments and the posterior joint capsule, causing hyperextension of the knee joint (back-knee) during ambulation (Fig. 7). This so-called recurvatum may progress to the extent that ambulation is seriously impaired by the pain and the sudden backward thrust of the knee posterior to the weight-bearing axis of the leg. A full-length above-the-knee brace must be provided if the hyperextension

Figure 7. Hyperextension of the knee joint (back-knee) 3 years after onset of hemiplegia.

cannot be controlled by adjustment of the short leg brace to provide some plantar flexion of the ankle joint.

Flexion contracture of the knee joint is a frequent complication in the HP. It can be prevented by adequate supervision and treatment during the early postapoplectic period. The injudicious use of pillows beneath the knee joint frequently contributes to the development of this disability. It is often called a "sitting contracture" with shortening of the hamstring muscles, particularly if there is predominant flexor rather than extensor spasticity in the knee joint. A well-padded posterior splint may be necessary to maintain the knee in extension during the interval between exercises by the physical therapist. If the spasticity cannot be controlled, blocking of the spastic hamstring muscles is a palliative measure which can be employed. Selective tenotomies are the final solution if extension in the knee joint cannot be maintained by a long leg brace.

The Foot and Ankle

Complications arising in the distal segments of the lower extremity — the foot and ankle — are similar to those encountered in the wrist and hand with the added factor of pressure and distortion produced by weight-bearing. Mention has been made of peripheral neuropathies secondary to pressure. Bilateral neuropathies occurring in diabetic

patients pose a serious handicap to ambulation. Such patients walk with an unstable ataxic gait. The use of a walkerette, rather than a cane, is necessary during ambulation.

Reflex dystrophy occurs with less frequency in the foot than in the hand. Weight-bearing should not be interrupted unless the patient has intolerable pain. Occlusive dressings of the lower limb should be avoided and blocking of the lumbar sympathetic nerves promptly undertaken. Daily exercises should be performed to prevent contractures in the knee and ankle.

The development of decubiti over the lateral malleolus and posterior aspect of the heels poses a serious problem and can delay early mobilization of the patient, particularly when the nonparetic extremity is similarly affected; however, ambulation should not be delayed unless the ulcer is on a weight-bearing surface. In some instances the application of a well-padded Unna boot will promote healing of the ulcer by preventing contamination and secondary infection of the wound.

Complications

Contracture of the calf muscles is the most frequent and troublesome complication encountered in the lower extremity of the HP. It prevents effective ambulation by producing a plantar flexion (equinus) deformity of the ankle, frequently combined with inversion in the subtalar joint (varus). This disability can be the result of a static deformity which may develop during the early flaccid stage of the hemiplegia in those patients who have been bedridden without adequate treatment. The pressure of tight bedsheets is sufficient to initiate the development of a "heel cord" contracture. If the limb is maintained in external rotation at the hip, pressure over the head of the fibula will further complicate the problem by causing peroneal nerve palsy. Daily range of motion exercises are usually adequate to prevent such a complication. The use of a well-padded posterior splint may be necessary, particularly if there is some active function in the calf muscles creating a dynamic imbalance in ankle function.

The predominance of spasticity in the calf and posterior tibial muscles further complicates the problem during the subsequent rehabilitation phase of the convalescence. The foot then assumes the characteristic equinovarus attitude when raising the leg with the knee extended or during ambulation. The foot is unstable and "throws" the patient. The short leg brace with an ankle stop and varus strap which is usually prescribed for the hemiplegic patient is inadequate. The heel comes out of the orthopedic last shoe and the lateral malleolus impinges on the lateral upright of the brace, causing pressure and even an ulcer. Adjustment of the brace or "correction" of the shoe is futile. The deformity must be treated energetically with stretching of the calf muscles. A sciatic nerve block with procaine may facilitate the exercises. Selective motor nerve or motor point blocking with a dilute solution of phenol will produce a more lasting effect. Tenotomy and manipulation of the foot may be the last desperate resort.

SENSORY COMPONENTS (S)

Mention has already been made of some of the problems of the patient with pseudobulbar palsy. This is also responsible for disturbances in the speech mechanism (dysarthria) or even aphonia. Some patients must be taught to communicate in writing, provided the dominant hand has not been involved and there is no appreciable aphasic component. The management of this problem requires the combined efforts of the speech therapist, psychologist, and occupational therapist when it is necessary to transfer dominance to the opposite hand.

One should not approach the language and communication defect from an isolated point of view. Visual disturbances may prevent or seriously impair progress in this direction as well as have a profound influence on the function of the upper and lower extremities. A discussion of this problem is beyond the scope of this paper, but mention should be made of some of the visual complications which can be readily evaluated, namely, cataract, peripheral blindness following thrombosis of the retinal artery, double vision secondary to extraocular palsies, hemianopsia, visual perceptual disturbances,[1, 5] and central blindness. From the practical point of view, the management of these problems in terms of rehabilitation consists of teaching the patient substitute compensatory patterns to enable him to function within the limitations imposed by the disability. Improvement in specific areas of impairment can be attributed to the resolution of the central lesion, rather than to the specificity of the "treatment."

A severe hearing loss constitutes a serious handicap to the patient who is in a rehabilitation setting. It is often overlooked in the absence of an adequate medical history and the lack of cooperation on the part of the HP attributed to poor motivation, organic brain syndrome, or even aphasia. The elderly person can show remarkable personality changes following the prescription of a hearing aid.

EXCRETORY FUNCTION (E)

Incontinence of bowel and bladder can often be the greatest single deterrent to successful rehabilitation of the HP. Too frequently, the indwelling catheter and enema are the immediate solution of the problem without regard to the potential of the patient and the long-term implications. Obviously provision must be made for adequate bladder drainage in the presence of urinary retention. By the same token, one must initiate early "bladder and bowel exercises" to prevent incontinence, by habitation. This consists of toilet training, just as with a child, with regular bedside encouragement, followed as soon as possible by similar bathroom activities. It may be necessary to suspend other rehabilitation procedures for 2 or 3 days to afford the nursing staff an opportunity to redevelop these habits in the cooperative patient. This should be undertaken during the early convalescent period while the patient is still in the hospital, rather than attempting it on the day of discharge, in order to satisfy the acceptance requirements of the re-

habilitation center, extended care facility, nursing home, or the family — whose standards are often the most stringent.

Incontinence associated with an organic brain syndrome poses a serious and often insurmountable obstacle, as discussed under Social and Psychiatric problems.

SOCIAL AND PSYCHIATRIC STATUS (S)

Mention has already been made of the encephalopathy resulting from dehydration and drug intoxication during the early postapoplectic period. This state should not be confused with the organic brain syndrome, which is an integral part of hemiplegia and persists throughout the entire convalescence. The rehabilitation effort extended on such patients, particularly those with left hemiplegia and incontinence, is unrewarding. Ambulation is difficult because of the lack of cooperation and associated severe perceptual disorders, particularly in the patient with parietal lobe involvement. Suitable placement of such patients should be arranged, rather than subjecting them and staff personnel to a protracted rehabilitation program.

On the other hand, the depressed HP with cerebral arteriosclerosis who has been abandoned by his family will often respond favorably when exposed to the stimulating social contact in a rehabilitation setting.

The agitated aphasic patient who is depressed because of inability to communicate is frequently considered psychotic, only to improve in the psychiatric facility when his problem is accurately evaluated and managed. Interpretation to the family is mandatory to prevent disruption of the household when the patient is returned to the community.

In considering the long-term follow-up of the stroke patient, mention should be made of the incidence of postapoplectic seizures.[2, 6] Varying statistics have been cited, depending on the interval following the onset of the stroke and the survival rate of the study group. The longer the period of survival, the greater the incidence of seizures. In the author's series of long-term patients in an older age group, the incidence was over 15 per cent.

The seizures usually involve the hemiplegic side and are followed by mild stupor and transient increase in paralysis of the affected arm and leg. The patient is admitted to the hospital as a "recurrent CVA," only to recover dramatically within 24 hours. Mobilization should be rapid following such an episode, to avoid an extended period of hospitalization. The patient should be placed on a maintenance dose of diphenylhydantoin.

Any discussion of the social and psychiatric complications occurring in the HP is not complete unless attention is directed to the necessity for complete involvement of the family unit in the rehabilitation process and careful consideration of the impact of the problem on all the members of the household.

SUMMARY

The management of the hemiplegic patient requires a complexity of services prepared to deal with a multitude of problems as they arise in

the course of an active rehabilitation program. Prevention as well as prompt recognition and treatment of these complications during convalescence and following recovery, will insure maximum restoration and maintenance of function consistent with the residual neurologic deficit.

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The Diagnosis of Speech Disorders in Brain Damaged Adults

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It is the dual purpose of this paper to review briefly the language disorders which occur with acquired brain damage in adults and provide a diagnostic modus operandi for the clinician who does not encounter large numbers of these patients in practice. When the help of a physician or speech pathologist familiar with these disorders is available, it should, of course, be utilized. Whether or not he is interested in diagnosis, it is hoped this review will provide the attending physician an orientation to the subject to equip him better for answering the questions of patient and family.

To achieve these goals, the subject will be developed in four sections: (1) normal language, (2) the classification of speech disorders, (3) neurological syndromes associated with speech disorders, and (4) a brief guide to differential diagnosis.

Speech is one of the most human of man's characteristics, and there is no greater tragedy than a disturbance of this process, unless it is a disorder of his ability to think.

"Speech," said Montaigne, "belongs half to the speaker and half to the listener," but in each man this dichotomy is united. He is speaker and listener both, and unfortunately damage to the brain may affect both of these processes.

In order to clarify the nature of language disorders it is appropriate to devote some space to the normal processes of speech. On occasion we shall use the terms speech, language, and communication interchangeably. Unless otherwise specified, these terms will refer to the whole process of communication, all elements of expression and reception, both halves of the dichotomy.

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NORMAL LANGUAGE

Communication is comprised of all of the behaviors human beings use to transmit feelings and ideas. It includes the use of gestures, pantomime, sounds, words, and the processes of hearing and understanding which interpret visible and oral symbols. The modalities by which we express information are referred to as *expressive* or *encoding* processes and those used in the understanding and interpretation of symbols are the *receptive* or *decoding* processes. These are high cortical functions.

Speech behavior varies greatly among normal speakers. An individual's personality, intelligence, dialect, social and educational experience, all contribute significantly to the broad range of differences which characterize each normal speaker.

It would be specious in the extreme to attempt a summary of the body of knowledge contained in the science of psycholinguistics. For our purpose we shall work backward and briefly describe those parameters of speech and language which assist in understanding the nature of pathology.

Fundamental to the whole process of producing and understanding speech is the intellect which underlies it. Although thought can exist in the absence of the ability to speak, it is unlikely that meaningful speech can exist without thought. It is for this reason that we have included in this paper a category of speech disorder designated *non-aphasic*. There is reason to believe that the process of language acquisition is, in a sense, independent of the intellect, but the uses to which this skill is put must depend on the intelligence which utilizes it. What distinguished Shakespeare from the man on the street was the ability of the great playwright to manipulate language in a brilliant fashion. Any pathological alteration in Shakespeare's intellectual powers would undoubtedly have destroyed his unique ability.

Similarly, the average man's speech proficiency depends to a large extent on his intelligence, and if this is decreased it is bound to diminish his ability to express himself.

Linguistics is the descriptive natural science which deals with message transmission among speakers of any language. All languages differ in their linguistic characteristics, but are composed of three systems: a system of sounds known as phonology, a system of grammar, also known as syntax, and the semantic or meaning system.

The smallest units of speech, called *phonemes*, generally divide into consonants and vowels and are the basic units from which words and sentences are constructed. The rules which determine how words are organized into sentences are called the grammar or syntax. Word order is controlled both by grammar and the semantic value, or meaning, of words.

This complex process of language organization, production, and perception is still poorly understood, with regard both to how and where it is organized in the brain. It is generally conceded that there is a dominant hemisphere and that it contains the locus for language. Some workers, notably Chomsky,[7] maintain that there is an anlage for language which is present at birth, prescribes the rules of language organi-

zation, and requires only the experience of life to add details. At best, however, our knowledge of these matters is rudimentary.

Speech Production

Breathing and swallowing are reflexive and function differently at rest and during speech. The average resting cycle takes about 5 seconds. In speech the cycle is adjusted; inhalation is brief but adequate to accommodate the long expiratory phase while the person is talking.

During speech we change the size and shape of the vocal tract and the characteristics of the sound wave by (1) vibrating the vocal cords, thereby converting air into audible sound (phonation); (2) moving the tongue, lips, and pharyngeal wall; and (3) differentiating sounds by closing the nasopharynx with the soft palate in order to prevent air from escaping through the nasal cavity.

The size and shape of the vocal tract is probably most extensively changed by movements of the articulators, of which the tongue is the most flexible. Its tip, edges, and center can be moved independently by the intricate and highly specialized network of muscles which comprise it. The lips are rounded and unrounded to change the shape and length of the vocal tract. Articulation may thus be defined as the interruption or modification of the air stream by the articulatory organs to produce the sounds of speech we know as consonants.

The process of consonant articulation cannot be ascribed solely to the action of the articulators. In addition to articulatory movements, phonemes have other characteristics which distinguish them from each other. Some sounds are voiced (combination of articulatory movement and vibration of the vocal cords), others are unvoiced, nasalized, or exploded. Phonemes are rarely produced in isolation but in a continuum of infinite variation and they are affected by their "environment," i.e., the sounds that precede and follow them.

The end-product of articulation during speech is *intelligibility*, but this depends not only on the precision of articulation but on the loudness of the speaker's voice, the anticipation of his utterance, our familiarity with the subject matter, and even background noise. Other essential acoustic characteristics of speech include rate, phonation, resonance, pitch, rhythm, and stress patterns. All of these factors contribute to the over-all quality of an individual's speech production.

CLASSIFICATION OF SPEECH DISORDERS

Any one or all of the linguistic systems involved in communication (phonemic, syntactic, semantic) may be impaired in the patient who has suffered brain damage. Let us now consider the three major diagnostic categories of speech impairment with special reference to the linguistic systems involved in each: aphasia (with or without verbal apraxia), dysarthria, and nonaphasic language disorders.

Aphasia

Aphasia (sometimes referred to as dysphasia) is an acquired language disorder with disturbances in all three linguistic systems. It is

characterized by a reduction of vocabulary or syntax in the production (expression) or understanding (reception) of spoken language. Aphasia excludes those language disorders associated with primary sensory deficits, generalized mental deterioration, or psychiatric aberrations.

In addition to impaired speech and comprehension, aphasic patients may have difficulty in reading (dyslexia), writing (dysgraphia), and calculation (dyscalculia). It is common for patients to have deficits of varying severity in these several categories; occasionally one or more of them is spared completely.

When an aphasic's difficulty is primarily in speaking and writing, it is often referred to as predominantly *expressive aphasia* (also motor aphasia, Broca's aphasia). Conversely, if the primary impairment is in understanding and reading it is called predominantly *receptive aphasia* (also sensory aphasia, Wernicke's aphasia). When the disorder appears to affect both output and input equally it is an *expressive-receptive* or *mixed aphasia*. (Many investigators believe that the severity of an expressive impairment is determined to a large extent by the severity of the patient's comprehension deficit.) A complete absence of language function is identified as *global aphasia*.

There is a broad range of differences among aphasic disorders regardless of etiology. The range encompasses differences in severity as well as type. There are patients who retain the ability to use only a few words; others may have a larger vocabulary but have trouble with uncommon words or grammar. Let us look at some of the common symptoms of aphasia.

REDUCED VOCABULARY. This is the most common. It may be reduced for all parts of speech (nouns, verbs, adverbs, etc.) or for only one or two word classes. As a result it is not uncommon for a patient to substitute words for those he cannot find. A substituted word is usually of similar meaning; for example, the patient may say *table* for *chair* but he will rarely say *lettuce* for *chair*.[1] These symptoms are manifestations of both syntactic and semantic impairment.

JARGON. Some patients produce unintelligible speech which may or may not have an intonational pattern similar to normal speech. Occasionally a meaningful word is interjected. Often they are unaware that they are using jargon and behave as if they expect the listener to understand.

PARAPHASIA. This term refers to the disorganization of the sounds or syllables in words. The patient may say *tevelision* for *television*, *I'm freeling fain* for *I'm feeling fine*. The paraphasic speaker produces recognizable sounds which are out of order, perhaps reversed, or clear substitutions of one sound for another. In a severe form paraphasia may be difficult or impossible to differentiate from jargon. Paraphasia is often accompanied by disorders of auditory comprehension. Unlike patients who show a marked decrease in output, paraphasics may overtalk.

AUTOMATIC SPEECH. Many of the words and phrases which normal speakers use are automatic (hello, goodbye). An aphasic patient may produce automatic words and phrases despite a total inability to speak voluntarily.[2] Automatisms commonly heard are profanities, the words of

a song, the recitation of serials (numbers, days of the week, months) and emotionally charged phrases or even sentences. Characteristically these same words cannot be produced in a nonautomatic context. Verbal automatisms are analogous to the involuntary movements of dyskinesias or the reflex movement of a spastic limb.

Comprehension Deficits.   The inability to comprehend the spoken and written word exists in practically every aphasic to a greater or lesser degree. It is often difficult to detect when it is mild. The section on diagnosis gives a practical approach to the problem.

Verbal Apraxia.   A certain proportion of patients with expressive aphasia will demonstrate this symptom as well. It is an articulatory defect but must be distinguished from dysarthria. Verbal apraxia results from a lesion involving the cortex or cortical radiations and as such is assumed to be due to a disorder of motor organization in the cortex. Dysarthria, as will be seen below, is a result of brain stem dysfunction.

Verbal apraxia is manifested as an impairment of phoneme production characterized by slow, labored speech, a high frequency of distorted sounds, particularly consonants,[10] and what appears to be marked inconsistency in the production of sounds. The patient may produce an intelligible (p) sound in one word and in another it will be distorted. When severe, speech is characterized by great effort, each sound seeming like an articulatory struggle.

As indicated above, verbal apraxia is often part of a larger aphasic syndrome. In a patient in whom verbal output is almost nil it may be impossible to determine how much of the expressive deficit is due to verbal apraxia and how much to aphasia. In those in whom verbal apraxia is the primary symptom it is unusual to find severe deficits in auditory comprehension, reading, or writing. In addition, these "pure" verbal apractics usually have little or no trouble with vocabulary or syntax.

Patients with apraxia do not have difficulties in reflexive functions of the speech musculature (chewing, swallowing, coughing), but they do have trouble initiating and performing voluntary movements of the lips and tongue.

Dysarthria

The term *dysarthria* refers to motor speech defects which result from trauma or disease of the nuclei or fiber tracts in and adjacent to the brain stem which subserve the speech musculature. Such pathology may affect any of the so-called acoustic characteristics of speech—articulation, loudness, rate, phonation, resonance, pitch, rhythm, and stress patterns. In the majority of dysarthric speakers articulation is the primary speech defect, usually on the basis of weakness or incoordination of the speech musculature. However, since intelligibility is the end-product of all the acoustic characteristics noted above, any one of them may contribute to dysarthria. For example, if a patient has a paralyzed velum and air escapes through the nasal passage, those sounds which normally require velopharyngeal closure will sound abnormal: *bowl* sounds like *mowl; he's a big boy* becomes *ees a ming moy.*

Dysarthric speech may sound slurred, muddy, or halting; words may be mispronounced and indistinct. Patients usually use complete sentences or phrases except when the disorder is severe, in which case they may resort to short phrases. Vocabulary and grammar are normal. The most severe dysarthric patients may be totally speechless (anarthria) and may easily be confused with aphasics. One can expect some of these patients to have difficulty swallowing and sometimes chewing.

For many patients with dysarthria, articulation is optimal when speech is produced slowly. This is particularly true when certain combinations of consonants are problematic (clusters of consonant sounds like *pl* in *place, please; str* in *street, strike; br* in *bring, break*). The patient with articulatory difficulty will often substitute for or omit those sounds which he cannot produce easily (e.g., *bing* instead of *bring*.)

Disorders of rhythm and stress are peculiar to cerebellar lesions. Pitch is monotonous and each syllable receives equal stress.

Palatal myoclonus is a rare symptom of dysarthria characterized by a rhythmic variation in the sound stream produced by regular, involuntary contractions of the soft palate. It has been described as "nystagmus of the soft palate."[1]

With the syndromes of aphasia and dysarthria described, it can be seen that the former may be characterized by aberrations in all three linguistic systems, the system of phonemes (sounds), the syntactic system (grammar), and the semantic system. Dysarthria, on the other hand, is a disorder of the sound system only.

Nonaphasic Language Disorders

This group of patients differs from dysarthrics and aphasics in important ways: (1) they show no evidence of difficulty with sound production; (2) they have no problems in understanding speech; (3) speech is fluent and they use complete sentences; and (4) vocabulary may be impoverished, but there are no apparent word-finding difficulties and no mixing of words or word parts. These patients are often confused and disoriented and have other symptoms of intellectual deficit. Eye contact may be poor; ability to attend is impaired.

The point of difference is that the structure and use of words and language is not abnormal in these patients, although the content and manner of speaking may strike the examiner as being abnormal. The same problem often arises with psychiatric patients. The only way that one can be sure of the diagnosis is to rule out specific aphasic or dysarthric deficits and at the same time identify intellectual impairment by psychological testing.

NEUROLOGIC SYNDROMES

Cerebral Vascular Disease

Stroke is the commonest cause of speech disorders in the brain damaged population. Although cerebral trauma or disease may produce a picture which is indistinguishable from that of stroke, depending on the

location, type, and severity of the pathology, it is not usual to find the same constellation of symptoms in these cases as with stroke.

Among the three major causes of stroke – thrombosis, embolism, and hemorrhage – there is no characteristic speech disorder based on etiology. Put another way, any of these can produce any of the language deficits described, the distinguishing factors being the location and severity of the lesion. For example, cerebral hemorrhages are generally acknowledged to be more serious than thromboses or emboli, but there may be equally severe aphasia with all three.

Aphasia. The most serious speech disorder following stroke is *aphasia*, which usually results from a lesion in the left hemisphere. It is believed that the left hemisphere is dominant in 97 per cent of people, regardless of handedness, and the dominant hemisphere is thought to contain the language centers. Reports[5] indicate that the incidence of aphasia in right-handed patients with a right hemisphere lesion is 1 per cent; it is 67 per cent when the lesion is left-sided. This might be expected. However, the literature as summarized by Piercy[8] describes a total of 80 left-handed aphasics with left hemisphere lesions and only 38 with right-sided brain damage. In other words, regardless of handedness, aphasia is statistically more frequent with left hemisphere lesions.

In clinical practice, therefore, aphasia is associated most often with syndromes producing right-sided neurologic deficits. These include right hemiplegia or hemiparesis and deficits in the sensory systems ranging from a loss of almost all sense modalities (light touch is usually spared) to isolated or combination losses of pain, hot-cold, vibration, and position sense. In addition, homonymous hemianopsia involving the peripheral field contralateral to the hemisphere lesion is not uncommon. Because of bilateral cortical representation, hearing on the involved side is not impaired.

More subtle deficits of brain function may be part of the syndrome. These include right-left disorientation, agnosia for body parts, and agnosia for tactile stimuli as measured by figure writing on the involved hand or tactile object identification.

Analogous to the agnosias are nonspeech motor disorders called apraxias, which are poorly understood. Many types have been described, two of which are often seen in left hemisphere lesions: ideomotor apraxia and ideational apraxia.[8] In the ideomotor variety the patient is unable to imitate the examiner's gestures even though there is no paresis in the right arm. He will be incapable of grasping the left ear with the right hand following a demonstration of the movement by the examiner. It is as though the brain has forgotten how to program the sequence of motor events required to perform this act. To test for ideational apraxia the patient is presented with an implement or tool and asked to use it in the characteristic fashion. Such patients may be unable to use a comb, toothbrush, or scissors properly.

In addition to the above, left hemisphere lesions may produce intellectual deficits such as memory loss, impaired judgment, or ability to think in abstract terms, and, less commonly, disorders of perception and perceptuomotor coordination.

NONAPHASIC LANGUAGE DISORDERS.   If we acknowledge that the left hemisphere–right hemiplegia syndrome is the prototype of a stroke lesion which produces aphasia, one may say for didactic purposes that right brain damage–left hemiplegia is most often associated with non-aphasic language disorders.[4] The sensory, motor, and visual disturbances in the left hemiplegic are analogous to those seen when the disorder is on the opposite side. That which most distinguishes these two groups is the character of the cognitive and perceptual deficits which occur with right brain damage, and, of course, the absence of aphasia.

Although intellectual deficits are sometimes present in patients with aphasia, they appear to occur less frequently and are less severe in the aphasic group. By contrast the left hemiplegic commonly presents a more varied and severe constellation of cognitive and perceptual symptoms. Disorientation and confusion are dense and longer lasting; memory, primarily for recent events, both visual and auditory, may be impaired.[9] Poor judgment and concrete thinking are common, and the patient's ability to learn is reduced. So-called perceptual and visual motor coordination deficits are also more common in the left hemiplegic.

The motor apraxias described as constructional and dressing are seen more frequently and in a more severe form in this group.[8] The former refers to the inability of the patient to perform such tasks as assembling blocks, copying designs, and doing jigsaw puzzles. Dressing apraxia is what it sounds like and may be due in some cases to imper-ception of the left-sided limbs.

It would appear that the language disorder identified as nonaphasic is a function of the damage done to the left hemiplegic's cognitive or intellectual processes. It is not, therefore, a linguistic deterioration but is related to the patient's ability to mentate.

Not infrequently it is difficult to distinguish between disorders of the language system per se and those of an intellectual nature; it is important to do this, since planning for the patient may differ markedly, depending upon the nature of the disorder.

For example, we recall a business executive who sustained a stroke as a result of a thrombosis of the right internal carotid artery. His left-sided motor weakness, hemisensory deficit, and homonymous hemianop-sia cleared within 2 weeks, but a mild communication problem, assumed to be aphasia because he was left-handed, remained. As a consequence, the patient was permitted to return to work about 3 months post onset. He was totally unable to do his job, had to be retired by the company, and shortly thereafter attempted suicide. Careful testing before he returned to work would have revealed, as was found later, that he was not aphasic at all but that his language problems were due to severe intellectual deficits. His judgment was impaired, his language impov-erished and concrete, and both auditory and visual memory showed marked deficits, so that he was unable to assimilate written or spoken material. With no intention of doing so he had fooled everyone with a quiet, appropriate social facade. It was only when he attempted to perform his old job that his deficits revealed themselves.

DYSARTHRIA.   Far less common than aphasia and nonaphasic sequelae of stroke is *dysarthria*, simply because vascular pathology

occurs less frequently in the brain stem than in the cerebral hemispheres. In the latter cases, branches of the internal carotid system are usually involved, while in the former the vertebral-basilar circulation is the locus. As implied in the description of speech disorders, dysarthria results from a disturbance of the nuclei or fiber tracts which serve the speech musculature and are therefore associated with lesions of the medulla.

Brain stem lesions will usually produce a variety of motor and sensory symptoms, the patterns of which are different from those of intracerebral lesions. For example, a patient with a brain stem lesion may have paresis in the right-sided limbs and a sensory syndrome involving both sides of the body. Often, there is evidence of bilateral motor involvement with unilateral predominance. If the lesion is more widespread and midbrain nuclei are involved, there may be disorders of the oculomotor system such as diplopia or ptosis.

Another motor disorder which is common with brain stem pathology is trunk or limb ataxia. This results from the involvement of fiber tracts leading to and from the cerebellum, which is in close proximity to the damaged area.

What characterizes the pathology of brain stem dysarthria is that there is involvement of both sides of the neuraxis when it occurs. Speech pathologists have observed that unilateral paresis of the speech musculature generally does not produce dysarthria.[3]

Occasionally the rare disorder known as palatal myoclonus will occur in association with dysarthria. This has been described earlier.

Brain Trauma and Disease

The steady increase in highway accidents has produced a growing reservoir of brain injured patients. These statistics, coupled with the growing competence of the medical profession to keep such patients alive, bring more and more of them to rehabilitation centers. With many, the least of their problems are motor and sensory residuals. As one often hears in rehabilitation work, society pays more for the knowledge in a man's head than the strength in his arms. Intellectual and language disorders are, therefore, catastrophic beyond all others.

In essence, the three language disorders described as consequences of stroke also occur following traumatic injury or disease of the cerebrum and brain stem. However, the patterns of occurrence vary in an interesting way.

With stroke the nonaphasic disorders are most common, aphasia is second, and dysarthria a distant third. Following trauma or disease, nonaphasic disorders are again most common, but dysarthria occurs more frequently than in stroke, particularly with certain kinds of trauma. It is beyond the scope of this article to survey the entire field of cerebral traumatic and disease states, but certain patterns will be noted.

In the preceding section on Stroke, the question of localizing the language centers within the dominant hemisphere was avoided since it is still debatable. It is believed that the third frontal convolution, the temporal lobe, and the parietal lobe all participate in language processes and that, in general, lesions involving the anterior part of this area are

associated with expressive speech and those of the posterior portion with speech reception. These facts are mentioned only to indicate that focal trauma or disease affecting the "language centers" in the dominant hemisphere may give rise to aphasia. For example, gunshot wounds, loss of substance, and intracerebral or subdural hemorrhage may involve these areas and produce some form of aphasia.

Severe concussion or contusion are often not associated with focal lesions. These patients may remain comatose for long periods and upon regaining consciousness exhibit a group of neurologic symptoms, among which the most common are dysarthria of a cerebellar type and trunk-limb ataxia. Motor and sensory deficits have a varied pattern and may be mild or severe; visual difficulties are often seen and intellectual losses are common. This constellation of symptoms suggests injury to the cerebrum and brain stem and is no doubt the reason for the large number of patients seen with dysarthria following such injuries.

There is increasing evidence that the thalamus and other sub-cortical structures may play a role in the genesis of either aphasia or dysarthria. Brain damage following trauma is often diffuse and spotty and it is not unlikely that the occurrence of these communication disorders may be due to sub-cortical dysfunction in some cases.

Because of the frequent occurrence of intellectual damage following head injury, nonaphasic language disorders are common. It is not unusual following head injury to find a patient with all three types of speech disorder – aphasia, dysarthria, and that due to some reduction in intellectual function.

Neoplasia and infectious processes can produce any variety of language disorder depending upon the severity and location of the lesion. We have seen postencephalitic patients looking very much like those with the postcontusion syndrome described above.

A BRIEF GUIDE TO DIFFERENTIAL DIAGNOSIS

It is perhaps a good rule that one should not attempt a definitive diagnosis of a speech disorder during the acute stage of the patient's illness. In the early weeks it is usual for patients to show more deficits than they will later, as a result of edema in and around the pathologic lesion.

The acute phase may last anywhere from 10 days to 6 weeks in the conscious patient. One must allow roughly the same period following emergence from coma. During this time it is wise to focus on systemic recovery and hold an expectant attitude with regard to intellectual and language disorders. Perhaps the most important clinical fact during this period is that many patients will recover language and intellectual function completely.[6]

The most fruitful way of approaching the problem of diagnosing a language disorder is to be guided by the basic pathology and nonlanguage neurologic sequelae. By pointing to the locus of the lesion, the type of language disorder may be suggested. For example, those with a lesion in the left hemisphere may be aphasic; those damaged on the right side

may be intellectually impaired; a brain stem lesion should produce dysarthria. Let us now approach the problem of making a distinction between these groups.

Test for Receptive Aphasia

The first task is to gauge the patient's ability to understand speech. Much of this can be done during the physical examination by observing the patient's responses to instructions. This requires a high level of suspicion, since it is easy to assume that the patient has understood a spoken command when, in fact, the examiner has given him visual cues.

The length and complexity of a command determine its relative difficulty. Following is a list in order of difficulty:

> Open your mouth.
> Close your eyes.
> Look at the door, look at the window.
> Is there a telephone in the room?
> Is your first name Charles? (use wrong name)
> Give me your hand.
> Look at the ceiling and down at the floor.
> Touch your right ear with your left hand (assuming the left arm is functional).
> Touch your left elbow with your left hand (which should provoke protestations of impossibility).
> Look for response to an absurd question like, "Do you see the camel in the corner?"

Test for Expressive Aphasia

The most fruitful approach to gaining an estimate of expressive ability is a sufficiently long conversation with the patient. Because of the patient's difficulty, there may be long silences. The examiner must be patient and resist the tendency to talk. After a few simple preliminaries, questions requiring long answers should be posed. Here is a list of sample questions in order of complexity:

> How are you? (or how do you feel?)
> Do you have any pain?
> Did you sleep well last night?
> What time did you wake up this morning?
> What did you have for breakfast?
> How did you get here this morning?
> What kind of work do you do?
> Tell me about it.
> Tell me about last year's vacation.
> Do you think television has a good or bad influence on children? Why?

Look for the following in an aphasic patient:

1. *Reduced vocabulary.* This is obvious when it is a gross reduction, e.g., "vacation – summer – nice mountains." Patients with a reduced vocabulary for nouns frequently circumlocute. They ramble on trying to clarify meaning in the face of an inadequate inventory of nouns. Sometimes only small words are omitted. Subtle losses may require listening to a long answer.

2. *Word substitutions.* These reflect a reduction in vocabulary, although they are probably not produced consciously. A mild aphasic might use the word *bus* for *car* in an otherwise normal sentence.

3. *Grammatical errors.* Keeping in mind the patient's premorbid educational level, a mild aphasic may do such things as use the wrong tense (*is* for *was*; *eat* for *ate*); use the wrong gender (*he* for *she*); leave off word endings (like the *ly* in many adverbs — *slow* for *slowly*); incorrect plural endings (*two book* instead of *two books*).

4. *Paraphasic errors and jargon.* These terms have been described earlier. Paraphasia refers to the transposition of sounds within words, i.e., *hopsital* for *hospital*; jargon and paraphasia are most familiar to us as double talk, although severe jargon contains no meaningful words.

Reading and Writing

To test reading ability the patient should be asked to read a sentence aloud from a newspaper or magazine. He may read every word but be unable to answer questions on the content of what he has read. If he can do this successfully, have him read a short paragraph and again ask questions on content. Since speech is liable to be impaired, ask yes-no questions (Is the paragraph about a movie actor?).

If the patient appears to read well but complains that he does not, this suggests attention or memory problems rather than aphasia. Frequently these patients complain that their vision is impaired though no field or acuity problems exist.

In testing writing ask the patient to write his name. Name writing is an automatic, overlearned response; most retain this ability. Then ask that he write a list of what he had for breakfast. The latter requires preservation of the capacity to generate written words from within. If he cannot do this, one may test his ability to write from dictation; this is a lower level task. Lower still is copying.

If one observes that the patient has trouble with the pronunciation of words, he may have *verbal apraxia*; this was described in some detail earlier. However, the differential diagnosis of verbal apraxia, paraphasia, and dysarthria is sometimes difficult even for the trained speech pathologist.

Nonaphasic Disorders

With regard to nonaphasic speech disorders, the same questions used to estimate speech and understanding capacity can give information about the patient's intellectual status. It is possible to distinguish confusion, disorientation, poor memory, concreteness, and poor judgment from language impairment. What is perhaps of greatest importance is that one be aware of the possibility that mild aphasia and an intellectual impairment can be confused. Whenever possible, all patients with brain damage should have psychometric testing.

Dysarthria

Since dysarthria by definition refers to motor impairment reflected in the acoustic aspects of speech, the symptoms can be *heard*. By listening carefully to a patient speak in extended production, symptoms will become apparent. Since what we hear in speech is much more than the pronunciation of consonant clusters, a test like having the patient

repeat "methodist episcopal" is not adequate for an evaluation of speech production. In the course of listening the patient's loudness, rate, pitch, rhythm, and particularly the intelligibility of his speech can be assessed. If the patient is asked to speak more rapidly, dysarthric symptoms will usually become more apparent. Having him read aloud is also a good way to make the diagnosis.

The performance of isolated movements (protruding the tongue, elevating the tongue tip) may give very little information, since these are often done perfectly though they cannot be combined into the smooth, precise, and rapid transitions required for normal speech. In severe cases one may see gross disorders of movement or incoordination.

EMOTIONAL FACTORS

It would be delinquent to conclude an exposition on the language and cognitive aspects of brain damage in adults without mention of what is perhaps the most important aspect of management in these patients — a constant awareness of the emotional devastation which has been visited upon them and their families. For we must acknowledge that after our best attempts at diagnosis and treatment we are often left with an irrevocably damaged physiology and a profoundly disturbed psyche. The process of recovery in these cases is primarily one of adjustment and accommodation to the disability. It is a slow and arduous process, one in which the traditional medical principles of diagnosis and treatment are not applicable after the acute phase. This kind of problem is a formidable challenge to the newly developing technology and philosophy of rehabilitation.

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Perceptual and Intellectual Problems in Hemiplegia: Implications for Rehabilitation

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Can a highly responsible businessman be entrusted to make dependable decisions if he suffers hemiplegia following a cerebral vascular accident? Will a hemiplegic who is mentally confused profit from a rehabilitation program? How long will recovery of mental function continue following a cerebral vascular accident? What is the relationship of mental functioning following cerebral vascular accident to prior mental life? These are only a few of the many questions which require clinical decisions every day. While action is often based upon the best fit of the findings concerning the patient, his condition, and the situation, the questions still linger after the decision is made and the patient is gone. It may therefore be useful to examine our current state of knowledge on the mental functioning of persons with hemiplegia. In this examination we may begin by pointing to some of the difficulties in this area. We will then draw on some of the more recent developments in the relatively young field of neuropsychology and relate them to some facets of rehabilitation.

But first, there are some substantive and classification difficulties. We lack a commonly agreed upon, viable taxonomy of cognition, how it develops in normal people, how it changes with age, and how it dissolves in pathologic instances. As a result a number of serious problems follow in considering changes in mental function. What changes — memory, perception, attention, motivation? When a hemiplegic fails to copy a picture correctly, why does he fail? Is it that he does not see it correctly, or that it has lost its traditional symbolic value to him, or that he cannot translate what he sees into an adequate and effective response? Does he see some things properly but not others? Is there an ordering or lawfulness to what he does? If there is not and if we cannot fix this with objective replicable markers, then how can we be sure of a patient's progress?

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Does impaired perceptual performance cause the patient's anxiety or is it a response to anxiety? These are some of the hidden questions behind the seemingly simple query, "Is the patient mentally intact?"

Several lines of recent investigative work provide helpful observations and concepts to guide our thinking. These different lines reflect the developments of a new field of inquiry and clinical work—neuropsychology. While in its more generic sense the field is concerned with the relationships between the central nervous system and behavior, there are at least three specific paths of study which bear directly on our concerns. All reflect developments in the past decade. These are (a) the attempt to develop objective mental tests which are sensitive to the presence of brain damage, (b) investigation into the differential functioning of the right and left cerebral hemispheres, and (c) attempts to modify behavior by modifying task conditions.

OBJECTIVE MENTAL TESTS

Mental tests may be seen as an attempt to translate features of the neurologic examination which is conducted in the office or at the bedside into objective psychometric measures which meet acceptable standards of statistical validity and reliability. While there have been hundreds of studies in which mental tests have been applied to neurologically impaired people to detect the presence of brain damage, these studies have, on the whole, proved to be promising but inconclusive. One of the more recent of the many surveys in this field suggests that diagnostic proficiency has hit accuracy marks ranging from 75 to 90 per cent.[5] It has been argued that the plateau has been reached because the mental tests were not based on clinical neurologic experience but on more traditional psychologic tests. Therefore, if one based mental tests on the clinical neurologic examination, then diagnostic acumen would be increased. On this basis, Joynt and Benton[5] pulled together the observations of a number of clinical neurologists who had noted that persons with brain damage were unable to persist at a motor task. For example, the patient might have difficulty in maintaining his gaze, holding his tongue in a thrust-out position, or saying "ah" for a 20-second period. They found that if one took a cutoff point where 97 per cent of normal persons passed, then 76 per cent of patients with brain damage also passed. Hence, if a patient attained a score below this level, then the likelihood of the presence of brain damage was very great. Ben-Yishay et al.[1] found that this test was relatively easy to administer to hemiplegic patients and that performance improved while the patients inhaled air enriched with oxygen.

This work suggests that we can have instruments sensitive to changes in mental functioning for these patients. Some implications for practice are quite apparent. Preliminary studies on Test-Retest changes in patients undergoing rehabilitation suggest that in the course of treatment, improvement in mental function can be demonstrated in the case of right hemiplegics, though not in left hemiplegics. Another example shows a different kind of implication; competence on mental

tests is highly related to competence in motor skill functioning. Using a battery of such tests, it has been found that one can predict the patient's eventual ability to care for himself and to ambulate, as well as how long he will spend on a rehabilitation program.[2]

Aside from the use of these facts as aids to clinical management, the findings suggest that one can use them to detect the efficacy of rehabilitation programs. A quantitative indicator of the relationship between functional outcome and objective measures can serve to detect programs which produce outcomes above or below the expected relationships. This factor is particularly pertinent in evaluating the duration of treatment, an important problem in the economics of patient care. The relationship can also be used to examine individual cases which deviate from expectations. Such deviations provide useful material for understanding processes which are relevant to rehabilitation. Still a third implication may be drawn from the following study. It has been demonstrated that some mental tests are highly correlated with premorbid educational level. Because of this known relationship, it is, therefore, possible to project what score a patient should achieve on the tests. Deviations from the expected scores yield objective indices of extent of mental impairment.

This line of work will lead eventually to a compendium of quick, easy to administer tasks which are derived from the observations of clinical neurologists but have been standardized on a sufficient number of normals and hemiplegic patients. These tools will be of value to assess mental function and change in mental function for persons who have become hemiplegic. Included in such a battery are tests of the following kinds: motor impersistence, two-point discrimination, psychomotor speed, auditory and visual attention span, scanning ability, and spatial designs.

But what of the patient who has suffered a series of minor cerebrovascular accidents and is on the way to a cerebral vascular accident which will lead to full-blown hemiplegia? Will a battery of brief tests like this provide information to predict hemiplegia? The prognostic significance of such a battery is readily apparent, and this area offers one of the important paths for research.

DIFFERENT MENTAL FUNCTION IN RIGHT AND LEFT HEMIPLEGIA

Different mental functions may be ascribed to the right and left cerebral hemispheres. It is generally held that damage to the left cerebral hemisphere is accompanied by a loss of language and ability to solve problems related to verbal skills, while damage to the right cerebral hemisphere is related to disturbances in visual spatial tasks. This modern view of localization theory has received substantial support from several quarters. (1) Patients who have been subject to interhemispheric disconnection procedures for epileptic seizures[7] behave as if there are basically two minds in the same body. If two different figures are flashed simul-

taneously to the right and left visual fields – for example, a dollar sign on the left and a question mark on the right – and the subject is asked to draw what he saw using the left hand, he regularly reproduces the figure seen on the left side of the field, that is, the dollar sign. If we cover up his drawing and ask him what he has just drawn, he tells us without hesitation that the figure he drew was a question mark. In this particular case, the one hemisphere literally does not appear to know what the other is doing. It might also be noted that when the brain is split in half anatomically, its functional properties need not be split in half. They may be doubled in the sense that one half duplicates the other. The split half effects and the duplication effects are not gross or obvious but require special tests to elicit them.

(2) In the case of hemiplegic patients there are over 100 studies in the past decade, most of which argue in favor of a similar disassociation in skills. Those with damage to the left hemisphere suffer from right hemiplegia and a consequent loss in verbal ability, while those with damage to the right cerebral hemisphere suffer left hemiplegia and a loss in visual spatial skills. Studies indicate that right hemiplegics profit more from nonverbal instructions than they do from verbal instructions. Left hemiplegics profit more from verbal instructions than from gestures.

In addition, it should be noted that in complex tasks which are dependent on both verbal and nonverbal abilities, competence is related to the patient's area of defect. For example, learning to transfer from a wheelchair to a regular chair, a complex skill, may be related to visuo-spatial skills in left hemiplegia, and to verbal skills in right hemiplegia.

However, the distinction between verbal and performance skills represents only one dimension of differential deficit in right and left hemiplegia. There may be other dimensions which might be overlooked. These include the following: (a) *Tilting space* – left hemiplegics tilt counterclockwise while right hemiplegics do not. For example, when asked to adjust a luminous line until it is in a straight vertical position, the left hemiplegic will say it is in the vertical position when it is actually at about "8 minutes to 12." A similar distortion occurs in the horizontal plane, when the left hemiplegic places the horizontal line at about "23 minutes to 9." It is of interest to note that those left hemiplegics who distort more, have more difficulty in ambulation. It is also of interest to note that distortions of the vertical occur only when the patient is presented with the task in a dark room. Under adequate lighting the distortion washes out. This suggests that ambulation in hemiplegia should take place in well-lit rooms.

(b) *Adaptive styles* – Left hemiplegics and right hemiplegics show different adaptive styles to difficult tasks. Left hemiplegics tend to belittle, omit, or minimize problems.[6] Right hemiplegics tend to admit the existence of a problem, but respond with anxiety as a preferred style. The drawings of a right hemiplegic, for example, are disorganized, uncertain, and insecure. The drawings of a left hemiplegic are marked by omissions, rigidity, and constriction. The reasons for these differences are unclear. In this particular study the right hemiplegics were aphasic.

The type of response may be a function of the fact that an aphasic is aware of his problem because he has to struggle to express himself. Furthermore, language disability is generally part of an interpersonal situation, so that the patient receives continuous feedback with regard to his inadequacies. Because he is made aware of his problem, he cannot deny it and becomes anxious. On the other hand, the left hemiplegic has no difficulty in speaking. He may be unaware of the visual and sensory defects which are part of his condition. However, this interpretation cannot be accepted without reservation, for there may be some patients who are so aphasic that they were not examined and these aphasics may be the group which shows denial.

Styles of adaptation deserve more extended comment because they have attracted widespread clinical interest. Well over half a century ago, it was observed that some hemiplegics literally denied the existence of a disability. The patient with a paralyzed limb might say that his arm is not paralyzed, but that he is lazy or doesn't want to use it. This literal denial of a disability, anosognosia, is noteworthy because (a) it occurs much more often in left hemiplegics than in right hemiplegics and (b) it occurs in a context of mental confusion. As the patient clears up mentally, the anosognosia dissipates. In rehabilitation programs, anosognosia or literal denial of a disability is a rare event, because most patients have passed the acute phase of their illness when they enter a rehabilitation program. The denial which occurs is implicit rather than explicit. The patient may admit to the presence of a disability, but in the next breath talk about how he will be cured. In brief, he refuses to think of the consequences of the disability.

This phenomenon has recently been demonstrated with regard to reading. Reading skills are a relevant area for investigation in rehabilitation, for they involve a daily life activity which is highly functional. In addition, they require skills which are not so readily related to the motor handicap. The patient might easily connect his inability to walk to his stroke, but with regard to visual habits such as reading or watching television, he might relate his inability to situational fatigue, lack of interest, difficulty in turning the page, or need for change of glasses. In a recent study conducted at the Institute of Rehabilitation Medicine,[9] it was found that hemiplegics who were asked, "Do you read a newspaper every day?" responded as follows. Of the 37 left hemiplegics, 25 (67 per cent) stated that they did not because they had difficulties, while 12 (33 per cent) stated that they did read the papers and had no difficulties. Of the 11 right hemiplegics, 10 (91 per cent) stated that they had difficulties while one (9 per cent) denied the presence of difficulties. One interesting finding which emerged was that the group who stated that they read the paper every day did less well on a test requiring a person to search through a visual field and less well on a test which required a person to match a sound pattern with a sight pattern, both of which tap the basic skills involved in reading. From this we can infer that the people who said that they read daily papers and did not admit to the presence of difficulties were actually denying disabilities which were demonstrated on objective tests. An additional finding discloses that

those who said that they read newspapers daily were involved in significantly more accidents on a rehabilitation program, lending support to interpreting the data as a phenomena of denial.

(c) *Speed of response* – It is also possible to show that left hemiplegics differ from right hemiplegics in speed of response. In looking at a visual display both groups tend to deviate in opposite directions from the speed with which normal persons examine the array. While both groups overlap normal time limits, half of the left hemiplegic patients perform the task too quickly. Very few left hemiplegic patients perform the task too slowly. By way of contrast, none of the right hemiplegics perform the task too quickly, while one third perform it too slowly. The behavior of the left hemiplegic may be characterized as impulsive and erratic. The patient glances at the targets instead of searching through them systematically. Increasing the time limits required to perform the task does not improve performance, for the patient is over and done with. On the other hand, the right hemiplegic moves very slowly through the task. His performance (except in a small minority of cases) is error free. Increasing the time limit for this kind of patient improves performance.

Why should there be deviations in opposite directions in left hemiplegia and right hemiplegia when we are considering the temporal dimension? A number of theories appear plausible. With regard to the left hemiplegic, the speed of his response may be related to his denial and omissions. Moving rapidly over a visual display might be part of the mechanism of getting rid of the problem. It may also be related to aspects of visual field defect and hemisensory syndromes which foster denial. With regard to the right hemiplegic, the slowness may be related to difficulties in internal language which are associated with aphasia. We might suggest that following a target requires the mediation of internal language. Indeed, thinking might be regarded as a patient's ability to talk to himself. For example, the patient may tell himself to keep looking for a target. An aphasic may have difficulty in talking to himself, just as he has difficulty in talking to others. This difficulty is reflected in the slowness of his performance. This observation has a number of implications for management. Left hemiplegics might be helped by being told to slow down when learning a task. The patient might receive instructions to the following effect. "Take your time. Look carefully around before you begin." The right hemiplegic might be helped by extending the time limits for him to complete the task.

MODIFYING THE BEHAVIOR OF HEMIPLEGIC PATIENTS

Modifying the Task

A line of work, deriving mainly from psychologic studies of animal behavior, also yields a method which is relevant to rehabilitation. Brain injured animals, whose abilities might be expected to be impaired, learn in a maze faster, slower, or at the same speed as normal animals, depending on the nature of the blind alleys as well as the true path. In short, a major problem of the brain injured organism is rigidity. Under certain task conditions a rigid subject will outperform a flexible one. Curiosity

in the non–brain injured animal may lead him astray. This view of the consequences of brain injury on behavior suggest that abilities of the brain injured are not truly lost as a result of the neurologic impairment. Rather they cannot be properly integrated or utilized in performance. The patient who fails a test under one set of circumstances may pass it under another set of circumstances.

This kind of phenomenon, where the brain injured will exceed the performance of normal persons, is well known in clinical neurology. The fact that brain damaged people can perform well when task conditions are changed has been demonstrated in several ways. (a) A brain damaged person will have difficulty in copying block designs which will be manifested by rotating the blocks. This kind of rotation is rare among non–brain damaged people. However, when the patient is permitted to view the target through a pinhole of light, for example, while wearing blinders, his rotations decrease if he is brain damaged. If he is not brain damaged, rotations increase. In a normal person peripheral stimuli facilitate performance. In brain damaged patients, they impede it. The reader may demonstrate the changes in task conditions by taking a sheet of paper, rolling it up so that it creates a narrow tube, and looking through it at the writing on this page. While a normal person is distracted by the narrowed field, the brain damaged person's performance is facilitated. (b) When asked to match a red button with a red handkerchief, a coin about the size of the button, or a needle, a brain damaged person will select the handkerchief, while a normal person will select the needle. If one replaces the red handkerchief with a white one, the brain damaged person will also select the needle. The task conditions can, therefore, influence the correct choice. If a hemiplegic has difficulty in learning, one should always examine the task conditions.

Task conditions can also be shown to influence the behavior of brain damaged people in a negative as well as a positive direction. The well-known phenomena associated with double simultaneous stimulation illustrate this point. When a brain damaged person is presented with a stimulus on one side of his body, he will recognize it. However, when he is presented with two bilateral stimuli simultaneously, he will respond to the stimulus on his intact side and ignore the stimuli on his impaired side. This holds true for all the sense modalities, including audition and vision as well as touch. It has been suggested that the asymmetrical dampening could be overcome by providing stimulation on the impaired side.

The most useful point in this approach is that it serves as an experimental model for a real life phenomenon. Rehabilitation is concerned with setting up task conditions that will enable the handicapped person to achieve mastery. Indeed, the manipulation of the task conditions is one of the most powerful tools which the rehabilitation worker has. Studies in our program indicate that if one can make the task easier, by providing additional cues, then patients who normally fail can be trained to succeed. This training has enormously beneficial psychological consequences, giving the patient a feeling of mastery instead of chronic disappointment and failure.

Modifying the Consequences of a Patient's Actions

There has recently been widespread interest in the principle that behavior is determined by its consequences. Activities which fill our needs, or are in some way rewarding to us, tend to be maintained. Activities which are unpleasant, anxiety-arousing, or in some way noxious, tend to be discontinued. This principle implies that one can influence behavior by systematically rewarding or punishing its consequences. The hyperkinetic child for example, can be taught to sit still for long periods of time by systematically praising him at predesignated time intervals for sitting still and ignoring him when he moves about. The application of reinforcement principles has met with some success in dealing with a wide range of clinical problems, ranging from complaints of pain, to obesity, to learning difficulties. Recently there has been some success in utilizing these principles to improve the behavior of hemiplegic patients in activities such as rolling a wheelchair more quickly, operating a key punch, improving verbal output in aphasia, and improving noxious habits in learning to ambulate – for example, toe dragging.[1] While this approach has a wide range of potential applications in the modification of skills and attitudes in hemiplegia, such applications must be carefully evaluated. At our present state of knowledge, the utilization of this approach must be considered only in terms of careful clinical considerations. Indeed, the selection of the behaviors to be reinforced requires a careful diagnostic statement of what the problem is. The kinds of reinforcement must be considered; the systematic application of reinforcement requires total control over a specific situation. Reinforcement in itself must be implemented by principles which are used in learning – for example, modeling and feedback. Finally there is the recognition that improvement in some behaviors in the therapeutic situation may not be reflected in other behaviors outside of the therapeutic situation.

Despite these qualifications, this approach may eventually provide a rational means for dealing with many of the more intractable problems in learning and behavior which are now lumped together as management problems. The approach offers a number of promising features, aside from the validity of the principle of reinforcement.

While we have stressed the relations between neuropsychology and rehabilitation by showing how findings in neuropsychology are applicable to rehabilitation, two novel lines of approach must be pointed out. First, with increasingly sophisticated application of techniques and theories from neuropsychology we will be in a position to consider a new area of therapy, the treatment of cognitive processes. This area of therapy will take its place alongside speech therapy, occupational therapy, etc. At this point we come back to the kind of questions which we posed at the beginning. What do we treat in a cognitive disturbance – a problem in perception, attention, or memory? The delineation of specific defects permits a more rational approach to their remediation. Recent work suggests that it is possible to demonstrate the existence of different types of disturbances in attention in hemiplegic patients. The isolation

of the type of attentional disturbance carries us a long way in this direction.[3] We can, for example, separate a difficulty in scanning the environment for information from a difficulty in keeping several things in mind at one time. A primary defect in the former condition would be treated differently from a defect in the latter condition. However, there are only two of several possible dimensions of attention which might be impaired.

Another line of approach which will probably be used in the future is the fact that rehabilitation is concerned with functional performance. This generally means how well does the patient take care of himself, ambulate, speak, etc. While current measurement of these skills is generally based on observations in the hospital setting, there will be emphasis on how their evaluation in more natural settings can be conducted. We will ask how well the patient cares for himself at home. But once having asked this question, we find we know little about such questions as how much does a normal person walk at home, take care of himself, or talk. We will then be concerned with the ecology of behavior of handicapped people — the study of handicapped people in their natural habitats. This kind of concern will greatly affect the practice of rehabilitation.

CONCLUSION

It is said of Samuel Johnson, the eminent English writer, that when he suffered a cerebral vascular accident, he was afraid that he was losing his reason, his most precious asset. In order to probe his sanity, he tested himself by composing a prayer in Latin. While few of us are capable of devising such a virtuoso self-testing technique, recent improvements in mental testing, in the understanding of different processes underlying mental function in hemiplegia, and methods of improving performance on mental tests, suggest that we are in a position to develop tools which can be used diagnostically and therapeutically. The fundamental questions asked at the beginning of the paper can then be answered with more sophistication than an educated guess.

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New Concepts in Lower Extremity Orthotics

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New concepts in the orthotic management of lower extremity disabilities to reflect technological advances are only now beginning to be introduced. The design of conventional leg braces has not undergone any basic change in more than a century, though modern metals such as aluminum and stainless steel are now being used in their construction.[1] Present designs of lower extremity braces have been empirically derived rather than being based on an analysis of normal human locomotion. Furthermore, braces are overdesigned to prevent breakage – which most likely is caused by poor fitting and poor alignment. Braces are therefore heavier than they need to be, as their function and alignment are far from being analogous to those of a normally functioning extremity.

The need for improved brace designs has been pointed out repeatedly in various reports of the Workshop Panels on Lower Extremity Orthotics of the Committee on Prosthetics Research and Development of the National Academy of Sciences–National Research Council,[13] as well as the *Report of a Conference on Prosthetics and Orthotics*[12] held in Washington in December 1966. Yet with the exception of the patellar-tendon weight bearing brace,[10] developed at the Veterans Administration Prosthetics Center in New York, the University of California at Los Angeles functional long leg brace,[15] and the dual-axis brace[3] developed at the Biomechanics Laboratory of the University of California at San Francisco, there have been no significant new brace designs. The patellar-tendon weight bearing brace is an excellent device for unweighing the limb below the knee. As such, however, the indications for its use are limited. Although the UCLA functional long leg brace allows the patient to walk with a free-motion knee joint and, thus, represents a functional improvement, its bulk and weight exceed those of the conventional long leg brace. The UC-BL dual-axis brace adds another degree

of freedom to the brace by permitting subtalar motion in addition to ankle motion. This, necessarily, requires greater mechanical complexity and adds to the bulk of the brace. Neither of these devices represents an improvement in the cosmetic appeal of braces.

The new concepts in lower extremity orthotics described in this paper are based on design which will allow the patient optimal mobility while achieving stability and support. Ideally, orthoses should provide joint motions which are as nearly similar as possible to those of the normal extremity.[7, 8] This should be implemented with a minimum amount of hardware of high strength, light weight, and cosmetic appeal. Toward this end, unique engineering principles such as the spiral helix can be utilized to effect ankle and foot control. There are new prosthetic alignment principles to effect knee and ankle stability without resorting to a knee lock,[2] and the force of impact at heel strike may be used to affect knee stability through a linkage which coordinates knee-ankle motions and incorporates a hydropneumatic control system.[6] Specifically, three prototype orthoses have been designed at the Institute of Rehabilitation Medicine which incorporate these principles.[14] Modern plastics technology and the latest information available in the analysis of normal human locomotion are considered in the design of these orthoses.[11, 14, 16]

PLASTIC SPIRAL ORTHOSIS

Studies of normal human locomotion have shown that transverse rotation is an important component.[4, 5] The transverse rotation may be considerable, consisting of approximately 23 degrees of relative rotation between the pelvis and the foot. With the exception of the UC-BL dual-axis brace, which in addition to ankle motion provides for subtalar motion, conventional braces allow motion in one plane only. The plastic spiral brace designed at the Institute of Rehabilitation Medicine, on the other hand, is believed to provide for controlled motions in all planes – that is, it adapts to transverse rotation as well as to motions in the frontal and sagittal planes. It is indicated for patients who lack motor power in the ankle-foot complex.

The spiral portion of the orthosis originates from the medial side of the foot plate, passes around the leg posteriorly, and terminates at the level of the medial tibial condyle. A horizontal band is attached to the spiral at the level of the calf. The thermoplastic used in the construction of the orthosis is Plexidur,* an amber-colored acrylic-nylon material (Fig. 1). The spiral configuration represents a new and unique concept which obviates the need for any metallic joints in the brace, yet permits controlled plantar flexion and dorsiflexion. The spiral unwinds on weight bearing to permit plantar flexion (Fig. 2). Removal of body weight results in a rewinding of the spiral, thus dorsiflexing the foot. Adaptation of the orthosis to transverse rotation is based on the principle of the spiral helix – unwinding and rewinding of the spiral produces transverse rotation. In addition, controlled eversion and inversion of the ankle is

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Figure 1.   The IRM plastic spiral orthosis.

provided by the application of the three point pressure system inherent in the spiral configuration.

This orthosis has been experimentally fitted to a number of patients representative of the various disabilities as well as age groups (Table 1). The patients' performance and acceptance of this device has been quite encouraging. Some of the advantages of the spiral brace over the conventional brace are:

Figure 2.   The spiral unwinds on weight bearing at heel strike, permitting plantar flexion.

Table 1. *Patients Fitted with the Plastic Spiral Orthosis*

SUBJECT	SEX	AGE	HEIGHT	WEIGHT (lb.)	DIAGNOSIS
F. L.	M	49	5′8″	170	Post-operative disk syndrome
J. C.	M	41	6′	195	Peroneal nerve palsy
T. Y.	M	68	5′5″	145	Spastic hemiplegia secondary to cerebrovascular accident
E. S.	M	48	6′1″	180	Post poliomyelitis
L. W.	F	39	5′3″	105	Multiple sclerosis
J. O.	F	2	39″	39	Spastic hemiparesis secondary to cerebral palsy
B. B.	F	55	5′5″	123	Muscular dystrophy
R. W.	F	12	5′2″	95	Quadriparesis secondary to encephalomyelitis

1. Compatibility of anatomic-orthotic motion, resulting in greater comfort and a more nearly normal gait.
2. Improved cosmesis.
3. Lighter weight (6½ ounces) reduces patient fatigue.
4. Interchangeability of shoes.
5. Built-in foot support.

Although the spiral brace design appears to be sound, and the functional performance of the patients fitted and their acceptance of the brace seem superior to our experience with metal braces, material breakage experienced in a number of fittings is a problem which has not yet been solved.

SUPRACONDYLAR KNEE-ANKLE ORTHOSIS

Another brace prototype designed at IRM termed the SKA (supracondylar knee-ankle) orthosis (Fig. 3) makes use of prosthetics technology in a orthotic application. It combines a modification of the PTS prosthesis[9] with above-knee prosthetic alignment principles to provide knee stability in patients who lack knee extensor strength as well as motor power about the ankle. This is achieved by immobilizing the ankle and foot in equinus with a laminated plastic orthosis extending to approximately 3½ inches above the knee. The equinus attitude results in alignment stability, producing a knee extension moment in the stance phase (Fig. 4). It therefore eliminates the need for a mechanical knee lock. Although the principle of placing the foot in equinus to achieve knee stability is not new and has been used in orthopedic surgery, it has not become a routine procedure, because patients thus treated may develop genu recurvatum or other structural changes in the knee joint over a period of time. In the SKA orthosis, genu recurvatum is effectively controlled by the anterior extension of the brace above the knee, counteracted by a force applied in the popliteal area. Mediolateral stability of the knee is assured by the supracondylar extensions. Three patients (two with poliomyelitis, one with muscular dystrophy) have been fitted with the SKA orthosis. Two of these replaced conventional long leg braces with knee locks and the third a UCLA functional long leg brace.

The SKA orthosis is a unitized structure made of a flesh-colored polyester laminate reinforced with nylon and fiberglass. This produces a closer fitting and more cosmetically acceptable brace. Furthermore, free

Figure 3.   The IRM supracondylar knee-ankle orthosis.

knee flexion in the swing phase not only results in a more nearly normal gait pattern, but conceivably in a reduction in energy consumption. The light weight of the orthosis (approximately 13 ounces) also aids in diminishing patient fatigue. Like the plastic spiral orthosis, it fits inside the shoe.

Figure 4. The equinus attitude results in alignment stability, producing a knee extension moment in the stance phase.

Figure 5.   The IRM hydra-pneumatic knee-ankle control system.

Figure 6. The hydraulic system coordinates knee-ankle motion. It offers knee stability during the critical period from heel strike to mid-stance and fluid resistance to plantar flexion, preventing foot slap.

HYDROPNEUMATIC KNEE-ANKLE CONTROL SYSTEM

An alternate design to the SKA orthosis is the incorporation of a hydraulic stance and swing phase system between the ankle and knee joints (Fig. 5). The function of such a system is stability of the knee during the critical period from heel strike to the mid stance phase of gait. At the same time it offers controlled fluid resistance to plantar flexion, preventing foot slap (Fig. 6). Plantar flexion causes the hydraulic fluid in the cylinder to be displaced upward, resulting in an extension moment about the knee joint. This reciprocating action also comes into play in the swing phase, where knee flexion produces dorsiflexion of the foot. A 90 degree dorsiflexion stop is used for standing stability and to substitute for push-off. This design, like the SKA orthosis, offers advantages over the conventional above-knee brace in terms of approaching normalcy of gait and energy consumption. The hydraulic property of the system serves as extra protection against accidental buckling of the knee.

A patient who had previously worn a conventional long leg brace with a locked knee was experimentally fitted with this device. He experienced no difficulty with knee stability. Further research and development is needed, however, to reduce the weight and bulk of the system and to determine its proper indications.

SUMMARY

New concepts in orthotics which are based on modern technological standards and an understanding of the kinematics of gait can have a positive influence on the rehabilitation process of the physically disabled. Orthoses which are designed to provide the patient with optimum mobility and permit motion which more closely resembles normal human locomotion enhance the patient's functional capacity in the activities of daily living and various vocational pursuits. The use of lightweight plastic results in braces which are less obtrusive and more cosmetically acceptable. Above and beyond the physical benefits derived from such designs in reducing patient fatigue, the psychological effects may have a profound influence on the rehabilitation process. The external badge of disability normally associated with the conventional brace can be greatly reduced if the orthosis more closely conforms to normal gait, is less obtrusive, and results in diminished energy consumption. Further research, development, and extended clinical applications to overcome material problems and to establish proper indications for these devices, will result in the application of new concepts in orthotics to a broad spectrum of patients with neuromuscular disabilities of the lower extremity.

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Rehabilitation in Chronic Obstructive Pulmonary Disease

A 5-Year Study of 252 Male Patients

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A quick glance at some of the current statistics on obstructive pulmonary diseases compiled by the United States Public Health Service shows that emphysema and its precursor diseases are on the increase. Between 1959 and 1964, for example, the number of reported annual deaths from emphysema rose from 7728 to 15,796 — an increase of 104 per cent. These were only cases in which chronic obstructive pulmonary disease conditions were listed as the primary cause of death. In many other instances, they were recorded as contributory causes.

During the same period, first visits to reporting physicians (excluding referrals) for bronchitis with emphysema rose from 61,000 to 181,000 (a 198 per cent increase), for chronic bronchitis from 230,000 to 421,000 (81 per cent), and for emphysema from 130,000 to 267,000 (105 per cent). During 1965, 36 per cent of all visits for bronchitis with emphysema, 13 per cent for chronic bronchitis, and 32 per cent for emphysema, were to hospitals. According to the last survey from 1965 to 1968, the number of new cases is now increasing at an even faster rate.

Social Security Administration studies of work disability allowances indicated in 1958 that obstructive pulmonary disease ranked second only to heart disease as the cause of permanent disability in men over 40 covered by Social Security. Strangely enough, no statistics are available

as to the over-all incidence of obstructive pulmonary disease in the United States. The nearest estimate, culled from different nonofficial resources, is that there are between 2 and 17 million people in the United States having some degree of chronic bronchitis, bronchial asthma, or emphysema.

The management of these patients is one of the most difficult and discouraging problems encountered in daily practice.[7] Since we do not have infallible tools for early detection and since patients are unable to recognize the development and progression of their disease, the therapeutic strategy becomes even more difficult. To compound this regrettable deficiency, there is also the profession's parallel inability to recognize by purely clinical observation the precise moment when chronic bronchitis, bronchial asthma, and pulmonary emphysema are transmuted from nagging chronic ailments to crippling diseases. By the time a patient is seen in the physician's office with the symptomatic triad of dyspnea, intermittent cough, and easy fatigability that follows even minimal physical effort — which prompted the patient to seek professional help — the structural damage to his lungs may be so far advanced that he no longer has the necessary cardiopulmonary reserve to fulfill his physiologic needs.

Current methods of treatment, which emphasize symptomatic relief, do not appear to arrest the progressive character of the disease, or to diminish the serious socioeconomic problems that it presents. As a rule, the patient is seen at this point in the private physician's office. The prescription is routine; it consists of bronchodilators, antibiotics, tranquilizers, and possible advice to buy an IPPB machine, coupled with a long list of negative recommendations. The patient is advised to "take it easy" and to resist any exercise. Now thoroughly frightened, the patient automatically interprets this as an injunction against *all* activities.

This symptomatic approach to treatment is motivated by the dogmatic concept that nothing can be done for these patients. However, there exists another medical approach which advocates a vigorous program of total rehabilitation; this clinical strategy encompasses postural drainage,[5] breathing training and retraining exercises with added oxygen, followed by vocational training or retraining. This will greatly benefit the patient, and is a logical and useful choice — in addition to symptomatic treatment — in the day-to-day management of these patients.

For some unaccountable reason, rehabilitation of patients with chronic obstructive pulmonary disease (COPD) is lagging behind rehabilitation of those with neuromuscular and skeletal disabilities. The reasons for this lag may be that (1) the rehabilitation of a patient with obstructive pulmonary disease is not as spectacular as the rehabilitation of a paralyzed patient; (2) the obstructive pulmonary disease patient has, admittedly, a prognosis of a shorter life span; (3) because of the COPD characteristic of slow deterioration, and the declining socioeconomic standing of the patient, his self-supporting productivity for the future is questionable, and therefore the financial investment is not fully

justifiable; and (4) because improvements in these patients cannot be measured by routine laboratory procedures, some physicians believe that they are purely psychological, due to tender loving care – and, at best, are of only short duration.

Clinical results during the last 20 years at the New York University Department of Rehabilitation Medicine strongly support the concept that rehabilitation of COPD patients can be as successful as that of patients with neuromuscular and skeletal disabilities. Statistically, the COPD patients, when rehabilitated, have a prognosis equally as good as the group having permanent sequelae following neuromuscular and skeletal involvement – as, for example, rehabilitated hemiplegic patients. It is evident that the vocational goal cannot always be reached in either of these groups; however, both groups of patients, when rehabilitated, can attain a meaningful degree of self-care.

It is not claimed that these rehabilitative measures will reverse permanent structural pulmonary damage. Their purpose is to teach the patient how to live with his limited cardiorespiratory reserve, and to train him for a job or for self-care commensurate with his physical and mental capacity.

Rehabilitation should be a multidisciplinary approach, and not only must the physician, the patient, and paramedical personnel take part, but also the patient's family must actively participate.[4]

Since the inception in 1949 of the respiratory rehabilitation program at the Institute of Rehabilitation Medicine and at Bellevue Hospital, over 15,000 respiratory cripples have been treated. They were from all walks of life, with a large number of them supported for at least 5 years prior to admission by welfare agencies or by their families.

A 5-year controlled study was undertaken of the use and nonuse of rehabilitation medicine in 252 male patients with chronic obstructive pulmonary disease. These studies demonstrated (1) that rehabilitation combined with routine treatment of symptoms is far more effective than the latter alone and (2) that a significant number of chronic obstructive pulmonary disease patients, who would otherwise remain helpless, can be trained to return to gainful employment and become once again useful members of society, or at least can be returned to self-sufficiency and self-care.

Another objective of this study was to arrive at a more accurate method of measuring apparent improvements – in order to determine if, indeed, these rehabilitative modalities should be included in the total management of these patients.

Because of lack of evidence in measuring the apparent improvement by routine laboratory methods such as spirometry and arterial blood gas determination, it was important that a more refined system of measurements be found to determine in which bodily function these improvements were attained. In view of the fact that these patients carried out their daily activities and exercises with more ease and increased endurance, it seemed that the best answer would be found by investigating the energy requirement of different activities – that is, by measuring the time needed to reach a steady state, the oxygen consumption during rest and work, the contracted oxygen debt, and the actual time of recovery.

SELECTION OF PATIENTS

Admission to the study was limited to men under the age of 65. Excluded were patients with acute respiratory failure, as well as those with evidence of active pulmonary tuberculosis, acute respiratory infections, acute heart failures, and previous chest or abdominal surgery. Candidates for the study were drawn from all referral sources common to admission in private or municipal hospitals, such as private or governmental agencies, the city welfare department, diagnostic centers, voluntary hospitals, Social Security clinics, and private physicians.

There were three groups of study patients: (1) those given a full course of treatment on an outpatient basis; (2) those who received a full course of treatment as inpatients; and (3) a control group of 50 patients who were selected from outpatients at Bellevue Hospital and were systematically identically treated except for the rehabilitative measures—and were followed solely on an outpatient basis. For this group, the screening criteria were similar to those of the other two groups. They were also selected to match the others, as nearly as possible, in clinical status, pulmonary function, duration of disease, and demographic and socioeconomic characteristics. The average age of the patients in the experimental group was $56\frac{1}{2}$ years and in the control group 57 years.

All three study groups have been followed up to today. All the patients in the experimental group made periodic visits to the physical therapists for observation or correction of their breathing patterns and postural drainage techniques. The control group was also seen periodically by the supervising physician to determine the progression of the disease.

Admission Procedures

On admission to the program, the experimental group—as well as the control group—were subjected to a complete clinical and socioeconomic evaluation consisting of: record of demographic characteristics; work history; evaluation of past and present clinical status and previous treatment; various routine blood tests; inspiration and expiration x-rays for measurement of diaphragmatic mobility; pulmonary function; arterial blood gas composition; and electrocardiogram at rest and following various levels of activity.

Laboratory Tests

Pulmonary function tests and pulmonary diffusing capacities were evaluated with and without a bronchodilator upon admission to the program. These tests were repeated three times between admission and commencement of the rehabilitation program. The tests were thrice repeated because it was considered important to avoid possible errors due to superimposed respiratory infection, as well as to familiarize the patients with the procedure, and to obtain better cooperation.

Simultaneously, the arterial blood gas composition was also evaluated. Pulmonary function, pulmonary diffusing capacity, and blood gas

composition were determined for each patient at the midpoint of treatment, at the time of discharge, and periodically following discharge. The patients who underwent reconditioning oxygen exercises were evaluated twice weekly for blood levels of carbon dioxide.

For spirometric studies, the closed-circuit Two-Belt Godard Pulmotest and Pulmo-Analyzer were utilized.

For arterial blood gas studies, the blood was drawn from the brachial artery with an indwelling Cournand needle, and the blood was analyzed for pH, carbon dioxide tension, oxygen tension, and oxygen saturation. For the carbon dioxide tension and oxygen tension, the Severenghouse and Clark electrodes were used, respectively. For repeated analysis of the carbon dioxide tension in the oxygen treated patients, the Astrup micromethod was used in order to avoid arterial puncture.[1]

Energy Cost Studies

Various levels of activities were standardized for energy cost studies and were carried out on admission, at midpoint, and at discharge. The levels of activity were in minimum, low, medium, and high energy cost: (1) loop weaving, 28 loops per minute while sitting; (2) floor-loom weaving, 11 loops per minute; (3) walking, 1.2 miles per hour; and (4) stair climbing, 13 steps per minute up and down.

The open circuit method was utilized for the energy cost studies. The expired air was collected in a Douglas bag and the gas was then analyzed on a Schollander gas analyzer and calculated at standard temperature and pressure dry (STPD). For arterial blood gas samples, the Cournand needle was used and remained in situ during activities.

As a baseline study, the patients' oxygen consumption in the supine position was recorded. As a reference point for measurement of the oxygen debt and recovery, the sitting position was used. For all the tests, the patients were fitted with either a mouthpiece or a tight face mask.

Three minutes were given for a warm-up period to approximate a steady state. The expired air was collected, sampled and analyzed at 1-minute intervals. The same laboratory tests were repeated upon the cessation of the work tasks. The cardiac effect of the work load was also measured by blood pressure and electrocardiograms before and upon the cessation of activities.

PROGRAM OF REHABILITATION PROCEDURES

The program outline,[6] besides the routine symptomatic treatment, consisted of: (1) relaxation exercises; (2) positional postural drainage, according to the distribution of the bronchopulmonary segments, preceded by inhalation of heated aerosols or bronchodilators introduced by an intermittent positive pressure breathing (IPPB) valve; (3) breathing training; and (4) reconditioning oxygen exercises[2] in three modalities: level walking at different speeds, cycling with added load, and stair climbing. During these exercises the oxygen was delivered by double trunk nasal catheter, with the flow of oxygen regulated to the needs of the individual patient.

The step-by-step program which each patient followed from admission to the point of discharge follows:

First Day: Morning—routine clinical evaluation; afternoon—evaluation of pulmonary function, blood gas studies, x-rays, and electrocardiogram.
Second Day: Energy cost studies in the above-mentioned exercise modalities.
Third Day: Paramedical evaluation—psychosocial and vocational.
Fourth Day: Indoctrination of the family and the patient to IPPB techniques and to the bronchodilator, manual or aerosol propelled.

TREATMENT PROGRAM

Fifth Day: Actual demonstration, with the patient and family participating, of relaxation exercises, postural drainage, and breathing exercises.
Sixth Day: Relaxing exercises, postural drainage, breathing exercises, and oxygen reconditioning exercises by the patient.

From here on the same treatment was practiced for 2 weeks, after which the patients were evaluated in terms of whether or not they had acquired the techniques. The oxygen exercise time was increased by individually graduated progressions, depending on the patient's tolerance. At the end of the fourth week, if the patient mastered his exercises, he was discharged. In patients who showed difficulty in mastering the techniques, the teaching was continued until the patient acquired the necessary knowledge.

The treatment program was identical for patients who were hospitalized and who were treated on an outpatient basis. However, there was some difference in the application of time. The inpatients were on 1 hour twice daily, and the outpatients had 1 hour once daily. All patients were individually evaluated and the program adapted to their needs. Group therapy was administered when feasible.

For the outpatients as well as for the inpatients, family participation was paramount. It was emphasized to the patient—and to the members of his family—that the ultimate goal of breathing training was to help the patient acquire a new breathing pattern which would allow him to make the most economic and efficient use of his limited cardiorespiratory reserve.[3]

Vocational Rehabilitation

Where vocational rehabilitation was indicated, patients were referred to the vocational counselor for either training or retraining. After the vocational counselor's evaluation, the patient was sent to the work sample unit, where he underwent simulated work experience of various kinds. He remained in the unit for a few days to 6 weeks and was evaluated for increase of work tolerance, prevocational evaluation of work potential and skills, testing of regularity in attendance, and possible determination of most appropriate work area in terms of energy requirements.

Conclusion of prevocational experience was followed by referral for placement, training or retraining, and homebound activities.

Follow-Up After Discharge

The patients were followed at regular intervals at the clinic, and once weekly for 3 months they saw the physical therapist for supervision and correction of their breathing patterns. After 3 months, the visits to the physical therapists were at quarterly intervals.

RESULTS

Pulmonary Function

The first column of Table 1 shows the pulmonary function of the 252 male patients on admission to the program. As may be seen, the respiratory rate on admission was rapid (21 per minute) and the tidal volume, which in normal people is 500 ml., was only 390 ml. However, the minute ventilation – by virtue of the increased respiratory rate – was within normal limits at 7.99 liters. Vital capacity was decreased to 78 per cent of the predicted value with the residual volume significantly increased to 238 per cent of the predicted value. Maximum breathing capacity was drastically reduced to 40 per cent of the predicted value. Timed vital capacity was decreased to 35 per cent at the first second, 45 per cent at the second, and 58 per cent at the third, compared to the normal values of 83, 88, and 93 per cent in healthy subjects. The diffusing capacity was considerably diminished to 8.5 ml. per minute per mm. Hg, indicating severe impairment (in our laboratory the normal values are between 15 and 30 ml. per minute per mm. Hg).

The relation of total lung capacity and residual volume is represented in Figure 1. As can be seen, the total lung capacity is enlarged to about 130 per cent of the predicted value, suggesting some structural

Table 1. *Average Values for Pulmonary Function in 252 Men Before and After Rehabilitative Measures**

	BEFORE	AFTER
Respiratory rate (per minute)	21	17
Tidal volume (liters)	0.390	0.420
Minute ventilation (liters)	7.99	7.14
Vital capacity	78%	78%
Residual volume	238%	210%
Total lung capacity	125%	129%
Residual volume/Total lung capacity	45%	44%
Maximum breathing capacity	40%	43%
Maximum midexpiratory flow (liters per minute)	30	45
Timed vital capacity: 1 second	35%	35%
2 seconds	45%	58%
3 seconds	58%	67%
Pulmonary diffusing capacity (ml. per minute per mm. Hg)	8.5	8.5

*Vital capacity, residual volume, total lung capacity, and maximum breathing capacity calculated from the regression equations of Baldwin et al. (Medicine, 27:243, 1948): the timed vital capacity is expressed as the percentage of the vital capacity expelled in 1, 2, and 3 seconds. Pulmonary diffusing capacity measured by the carbon monoxide steady state method (Comroe, J. H., Jr., et al.: The Lung: Clinical Physiology and Pulmonary Function Tests. 2nd ed. Chicago, Yearbook Medical Publishers, 1962, p. 114).
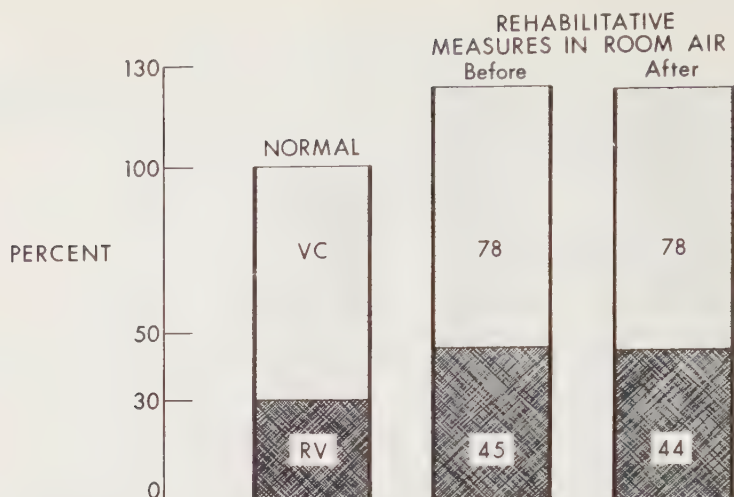
Figure 1.   The relation of residual volume to total lung capacity.

changes in the lungs. It can also be noted that the ratio of total lung capacity and residual volume is increased to 45 per cent instead of the 30 per cent observed in healthy subjects.

The pulmonary function upon discharge may be seen in Table 1, column 2. The respiratory rate is significantly decreased from 21 to 17 cycles per minute. Tidal volume is slightly increased. Total minute ventilation, however, decreased from 7.99 to 7.14 liters. The vital capacity did not change, and neither was there a significant change in residual volume. Maximum breathing capacity, timed vital capacity, and pulmonary diffusing capacity remained essentially the same.

In Figure 1, the last column shows that there were no significant improvements in the ratio of total lung capacity to residual volume.

Blood Gas Composition

The blood gas composition on admission and at discharge from the program is seen in Table 2. Before rehabilitation, resting oxygen saturation was 94 per cent, carbon dioxide tension 42 mm., and pH 7.38. In sedentary work, arterial blood oxygen saturation fell to 89 per cent, carbon dioxide tension rose to 44 mm., and pH remained stable. In heavy work, arterial blood oxygen saturation dropped further to 85 per cent while carbon dioxide tension increased again to 49 mm. The pH did not change appreciably.

Result of Postural Drainage

Figures 2 and 3 indicate the sputum production during postural drainage in a sampling of patients. In both of the groups — those with bronchiectasis and those with bronchitis or emphysema — sputum production was significantly increased. For instance, the bronchiectasis patients, without postural drainage, produced on the average about 100 ml. of sputum; with postural drainage, the sputum production increased to an average of 250 ml. Average sputum production in the group with

Table 2. *Average Arterial Blood Gas Composition in 252 Patients Before and After Rehabilitative Measures*

CONDITION	OXYGEN SATURATION (Percentage)		CARBON DIOXIDE TENSION (mm Hg)		pH	
	REST	WORK	REST	WORK	REST	WORK
Before rehabilitation:						
Sedentary work	94	89	42	44	7.38	7.38
Stair climbing	94	85	42	49	7.38	7.37
After rehabilitation:						
Stair climbing	95	87	42	44	7.38	7.38

chronic bronchitis or emphysema, including those who, on admission to the program, had no sputum production, increased from 9 to about 49 ml.

Energy Cost Studies

The results of energy cost studies before and after rehabilitation are shown in Figures 4 to 7. Oxygen consumption in the supine position and in the sitting position, before and after rehabilitation, was somewhat higher in these patients than in the healthy controls. During the warm-up period and work, oxygen consumption in the control group reached a steady state in 3 minutes and leveled off, keeping pace with the metabolic demands. In the patients before rehabilitation, oxygen use did not reach
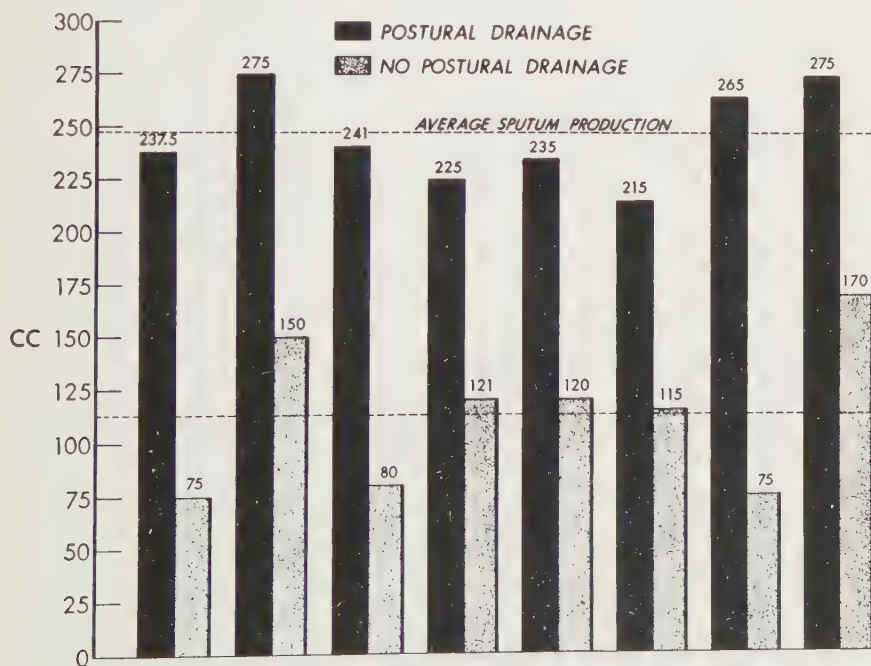
Figure 2. Sputum production in eight patients with bronchiectasis, with and without postural drainage.
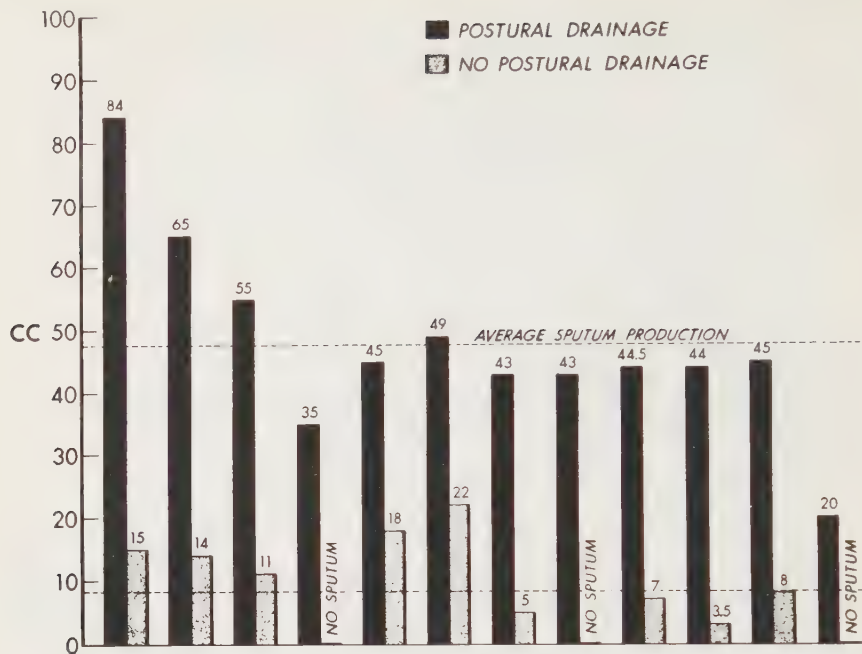
Figure 3. Sputum production in 12 patients with obstructive diffuse emphysema, with and without postural drainage.
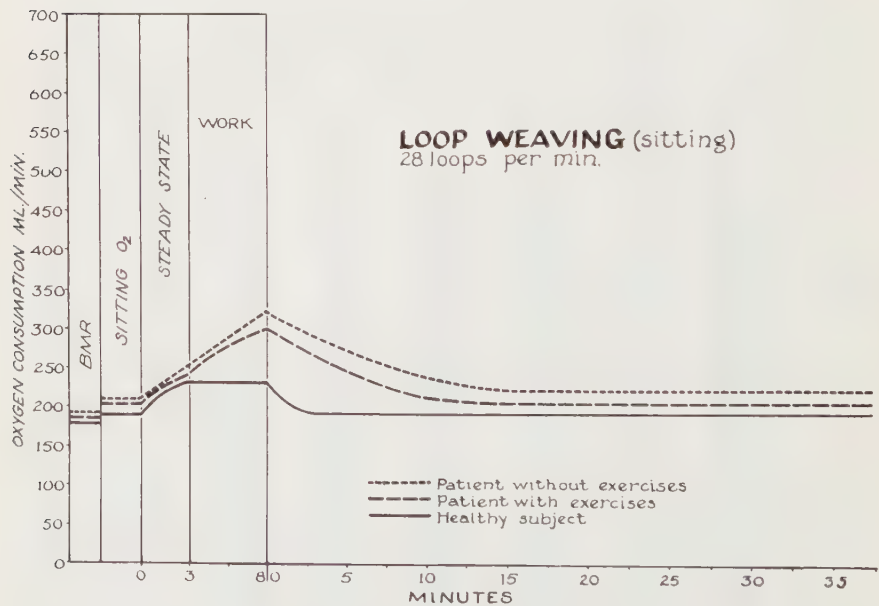
Figure 4. Oxygen cost and recovery from oxygen debt during loop weaving in normal subjects and in 10 patients before and after training.
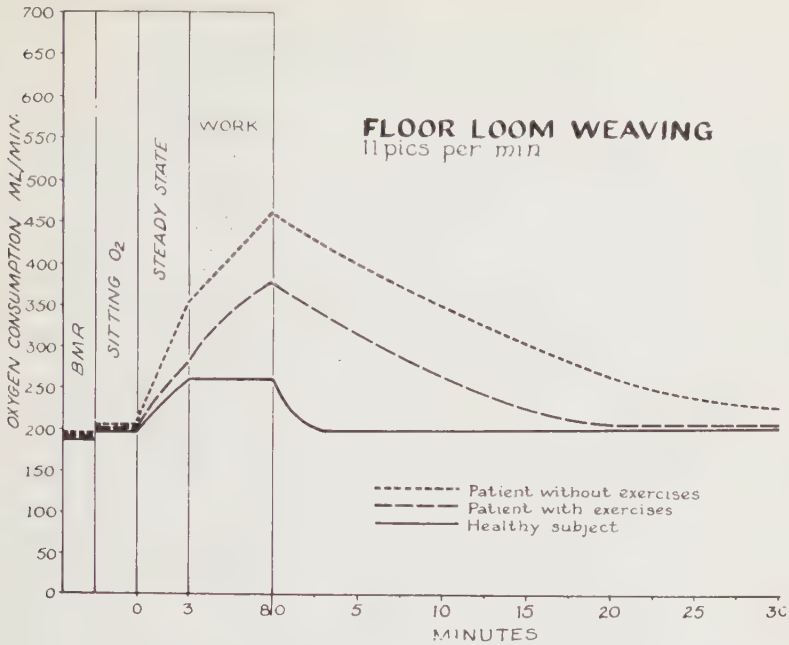
Figure 5. Oxygen cost and recovery from oxygen debt during floor loom weaving in normal subjects and in 10 patients before and after training.
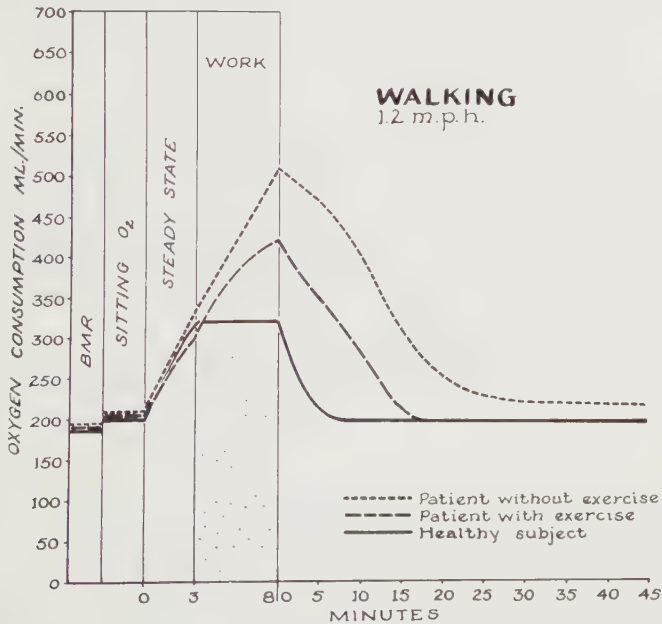
Figure 6. Oxygen cost and recovery from oxygen debt during level walking at 1.2 miles per hour in normal subjects and in 10 patients before and after training.
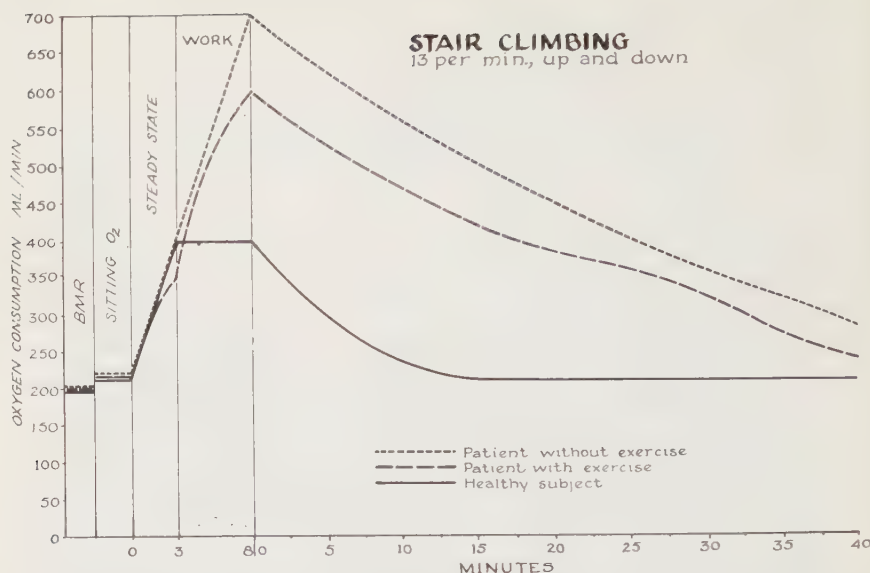
Figure 7.   Oxygen cost and recovery from oxygen debt during stair climbing in normal subjects and in 10 patients before and after training.

a steady state after 3 minutes but continued to increase. The contracted oxygen debt was larger and recovery was slower than in the control group. Following the rehabilitative measures, oxygen consumption still did not reach a steady state after 3 minutes, but it tended to level off. Oxygen debt was significantly smaller and recovery was faster.

Result of 5-Year Follow-Up

Table 3 indicates the clinical status of the all-male experimental and control groups. As noted, 5 years after discharge from the program, 25 per cent were able to assume full-time employment, compared to 3 per cent in the control group. In the experimental group, 19 per cent were restored to a degree of self-care, compared to 5 per cent of the control group. In the experimental group there were 8 per cent who needed nursing home care, compared to 17 per cent in the control group. Most

Table 3.   *Results of 5-Year Follow-Up After Discharge*

	EXPERIMENTAL GROUP (N = 252)	CONTROL GROUP (N = 50)
Return to previous occupation, still working	6%	3%
Returned and placed in a job, still at work	13%	0%
Trained but never placed in a job	6%	0%
Able to care for self	19%	5%
Placed in a nursing home	8%	17%
Lost for unknown reasons	18%	27%
Died of respiratory failure	22%	42%
Died of unrelated causes	8%	6%

noteworthy is the mortality rate, which was 22 per cent in the experimental group and 42 per cent in the control group.

DISCUSSION

There is a clear indication from the existing statistics that the incidence of obstructive pulmonary disease is reaching alarming proportions, disrupting the socioeconomic status of families and adding a considerable burden to communities and to hospitals.

It is interesting to note that although numerous agencies, governmental as well as private, are aware of the chronic obstructive pulmonary disease explosion, there are no reliable statistics available as to the number of people suffering from the disease. Moreover, there has been no future planning of how to cope with this ever-increasing problem, medically or economically.

According to medical history and observation, the disease progresses slowly to the crippling stage. In the early stage, when the patient is seen with easy fatigability associated with slight dyspnea, he still is able to benefit from symptomatic treatment. Only when a massive destructive process takes place in the pulmonary structure following an acute bout with influenza or pneumonia do the compensation mechanics start to fail, and the patient is now converted from a chronically ill person to a potential respiratory cripple.

Once the crippling stage is reached, rehabilitation, except for a small number of patients, cannot do more than teach the patients how to live with their limited cardiorespiratory reserve. The best time to include rehabilitative measures in the over-all management of these patients is during the transition period of quiescence. Unfortunately, most of the time this is not done, because: (1) the treating physician understandably is reluctant to refer the patient to another physician, since he has followed the patient for a long time. Many physicians are also not convinced that rehabilitation produces objective improvements that can be measured by routine laboratory methods. (2) There is an accepted misconception that nothing can be done for these patients besides the routine symptomatic treatment. (3) The high costs of rehabilitation treatment do not justify their employment.

As analysis of our study indicates, none of these objections to rehabilitative therapy for COPD patients are based on viable data. In day-to-day experiences with 252 patients over a period of 5 years, we determined that: (1) while spirometric measurements in our and other laboratories provide only rough estimates of pulmonary performance and fail to reflect the apparent gains, energy cost studies can and do record and quantitate the clinical improvements observed following rehabilitation treatment.

(2) The earlier the rehabilitation treatment is started in the history of COPD, the greater the cumulative benefit to the patient. The COP illnesses are not of sudden onset; they are slowly progressive and subject to rehabilitative treatment from the very start. Rehabilitation, therefore, should start long before the pulmonary diseases reach the crippling stage. The later rehabilitation has started, the less it can accomplish for the patient, since much of the damage to the pulmonary structure

is irreversible. Therefore, the longer rehabilitation is delayed, the more costly it becomes to the patient, to his family, and to society.

(3) The relative dollar values of rehabilitation programs in COPD are a reflection of the medical and psychosocial values the treating physician actually assigns to rehabilitative modalities. Our experience has shown that the latter values are very high — and therefore that the costs of rehabilitation treatments are not unreasonable.

The rehabilitative programs as outlined here were, of course, carried out in a hospital setting. Experience in this and other centers has demonstrated that because of the medical and paramedical personnel and facilities needed for such programs, medical economics probably will not allow such programs to be conducted in a private physician's office.

SUMMARY

A 5-year treatment and follow-up control study of the values of rehabilitative programs in 252 male COPD patients and 50 similar patients treated symptomatically but without rehabilitative modalities demonstrated that 25 per cent of the experimental group were able to return to full-time gainful employment, compared to 3 per cent of the control group and that the death rate in the control group was 42 per cent, as compared to 22 per cent in the experimental group.

The improvements observed in the experimental group occurred in the absence of significant changes in spirometric and other routine laboratory tests. However, standard energy cost tests clearly demonstrated the extent of measurable improvements in COPD patients treated by rehabilitative modalities. Since rehabilitative measures cannot change the course of irreversible disease, these measurable gains most likely are due to the more economic use of cardiorespiratory reserves and the decrease in the cost of breathing due to acquiring a more efficient breathing pattern.

In view of these quantitatable results, rehabilitation modalities should be included in over-all management of all COPD from the time of diagnosis — regardless of how early or late in the history of the disease.

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Rehabilitation of the Cancer Patient

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The challenge in rehabilitation of the cancer patient lies in the extent and the variety of the disease-related and treatment-related disabilities presented. There may be direct or remote effects on the nervous system, the musculature, the bony skeleton, or other internal organ systems. Current estimates by the American Cancer Society show that over ½ million people in the United States will develop cancer each year. One in three of these eventually will be considered to be cured. The rest will develop recurrent or metastatic cancer and will require additional treatment. Time of survival is a time lengthening with the increases in methods of control of disease. Both "cured" and "controlled" patients have frequent need for treatment of disability.[16]

The first step in the provision of rehabilitation care is the prompt recognition by the treating clinician of the presence of existing disability and, ideally, the recognition of potential disability, such as may follow scheduled treatment. Initial examination and evaluation of the patient and the provision of the first orders for care can be made at the bedside, without waiting for the patient to reach a status of readiness for being moved to a rehabilitation service area.

The disability encountered may be either acute or chronic. Acute disability is found in the immediate postoperative period when there may be enforced immobilization, pain, fear, and confusion. Chronic disability is found where there is a long-lasting handicap. Prompt attention for the patient in the form of preventive as well as definitive rehabilitation therapy can reduce the degree of disability and also the time needed for recovery. This emphasizes the advantage of early and dynamic assistance and readjustment. It should be noted that cancer-related disability, especially when chronic, affects all the spheres of living for the patient. Therefore, it is in marked contrast to the problem of acute illness, which precipitates only temporary derangement in social, economic, and vocational areas.[4, 10]

In the specific treatment for cancer three principal approaches are followed, either separately or in combination. These are surgery, radiation therapy, and chemotherapy. In the hope of securing a cure, the approach is usually radical, unless evaluation has determined that only palliative treatment can be offered. Radical procedures, however necessary, exact a toll from the patient, leaving an extensive physical deficit to which he and his family must make adjustment.

For surgical cases, preoperative as well as postoperative training and counsel are of benefit. Dependent upon each patient's needs and findings there should be an individually prescribed care program. Provision should be made for physical and occupational therapy, training in the activities of daily living, psychosocial evaluation and counselling, as well as the supply of such orthotic or prosthetic devices as may be required.[3]

As early as possible in the course of examination and care, a goal for the patient should be established. Suggested are the categories of "restorative," if the patient can be expected to become able to return to premorbid status without remarkable residual handicap; "supportive," if ongoing disease or handicap must persist, but the patient can expect to achieve elimination of as much disability as possible by proper training and treatment; and "palliative," if there is increasing disability to be expected from progressing disease with associated decrease in functional capacity, but where appropriate provision of treatment will eliminate some of the complications which might otherwise ensue. These latter would include bedsores, contractures, problems in personal hygiene, and emotional deterioration secondary to inactivity and depression.

When a status of disability has become permanent, social service assistance becomes of increasing significance. The social service worker can provide detailed inquiry into the family structure and develop intimate knowledge of the living and possible working conditions to be faced by the patient after discharge from the hospital.

The complex psychosocial and vocational problems consequent to chronic disability are not transient but are residuals for which solution must be energetically pursued. Both the psychologist and the vocational counselor can provide valuable assistance. The ultimate goal of job placement for the disabled patient with a cancer diagnosis is often a difficult objective to attain. Positive understanding is needed by the employer to modify problems of acceptance of the employee's cancer diagnosis. Planning helps circumvent limited ability for the patient in the use of public transportation and aids in the facing of competition in the labor market and the possible need for specialized job placement within the limitations of residual disability.[8, 12d]

In an effort to develop and demonstrate an active program in the rehabilitation care of the cancer patient, a cooperative study has been conducted by the Institute of Rehabilitation Medicine and Memorial Hospital for Cancer and Allied Diseases in New York. The first patient treated in this program was a 49-year-old male who underwent a hemi-corporectomy (a translumbar amputation at the L4-L5 level) in September 1964. The surgery was performed at Memorial Hospital for

Figure 1. Translumbar amputation between L4 and L5 (hemicorporectomy).

treatment of inoperable epidermoid carcinoma of the urinary bladder, which had spread locally to involve the pelvis and was causing intractable pain. Postoperatively the patient was transferred to the Institute of Rehabilitation Medicine (Fig. 1). Rehabilitation was started with bed

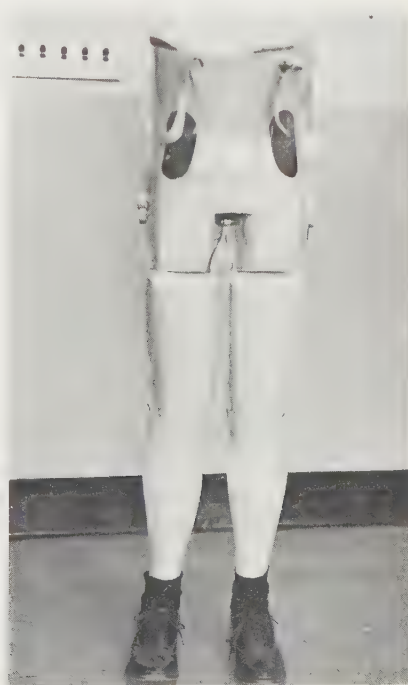Figure 2. Full prosthesis – translumbar amputation.

Figure 3.   Ambulation with Lofstrand crutches – translumbar amputation.

exercises for strengthening the upper extremities. The patient was prepared for eventual sitting in a prosthetic jacket, wheelchair propulsion, independence in activities of daily living, and ultimately he was provided with a full prosthesis in which he was trained to stand and ambulate (Figs. 2 and 3). Finally, he received driver training and obtained his driving license, after passing his road test. He is active, out and about at the present time, $4\frac{1}{2}$ years after his surgery. This cooperative program has encouraged increasing referral of patients for rehabilitation, so that the visits can be made as early in the disability as possible and a constructive program developed for ongoing care.

The disabilities presented by the cancer patient represent a general category of all disabilities and do not differ essentially from those arising from other diagnostic backgrounds. There are, in addition, disabilities particularly related to cancer and its treatment, such as the neuromyopathies secondary to the remote effects of cancer on the nervous system, the secondary effects of treatment agents used, and focal effects such as pathological fractures. The disabilities depend upon both the anatomical or organ system affected by the cancer and upon given treatment.

Since approximately 50 per cent of cancer patients are over 55 years of age, they may, therefore, be victims of additional forms of chronic disability, the result of other disease prevalent in this age group and adding to the need for care.[1] However, the majority of patients who have been referred for care in our cooperative program have been in the employable age group, with an average age of approximately 49 (Fig. 4).
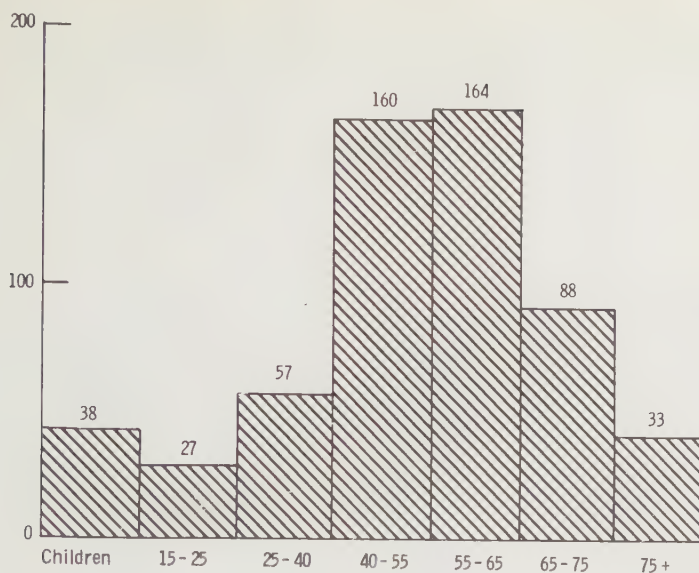
Figure 4.   Age distribution of patients with cancer-related disability.

Regardless of the classification of the type of disability, early availability of care is important. Rehabilitation should not wait to follow completion of definitive treatment, but should start with onset or recognition of disability.

Rehabilitation treatment is varied according to individual case findings and need, and this can best be categorized by disease region and cancer treatment procedure.

AMPUTATION AND DISARTICULATION FOR BONE AND SOFT TISSUE MALIGNANCY

For the prospective lower extremity amputee, preoperative training is of great value. During this preoperative period, the patient has no discomfort from a surgical wound, has not been weakened by a period of immobilization, is not affected by medication for pain, and has not developed a fear of falling due to lack of limb support. The security gained at this time from training in crutch ambulation or the use of a walker is of great assistance during postoperative recovery and speeds the progress of rehabilitation. Postoperatively, the patient can be instructed in strengthening exercises for the residual normal extremities and his ambulation training can be continued as is expedient.

Consideration and discussion of the provision of a prosthesis with the patient who is to have an amputation for cancer should be an early part of the rehabilitation planning and should begin preoperatively if possible. This increases the patient's understanding, elicits greater confidence in his postoperative status, and increases his hope for his future as well as his motivation and his own efforts toward recovery.[12c]

The patient with a cancer-related disability is in need of the same degree of understanding and rehabilitative assistance as the patient with a similar disability from another diagnosis. The consideration of "cure" should not restrict the rehabilitation program or planning for a prosthesis, as patients who undergo amputations for metastatic disease survive for an average of 3½ years and occasionally for 5 or 10 years. During these periods of many months to many years, they can derive beneficial service from prostheses. Amputation because of a malignant tumor does not constitute an a priori contraindication to early prosthetic fitting. Indeed, if there is no evident metastasis and the stump is suitable for fitting, a limb should be fitted at the earliest possible time permitted by the surgeon.

The new approach of fitting a prosthesis either immediately or early in the postoperative period is of particular value for the cancer patient.[1] In both instances, there is immediate postoperative application of a light, thin, wound dressing covered immediately by a tight cast of elastic plaster of Paris, which conforms exactly to the contour of the stump. This material, in contrast to elastic bandaging, ceases to create any elastic constrictive pressure as soon as it has hardened, and creates sufficient support to prevent edema and swelling of the stump. Also, it appreciably cuts down on postoperative pain and discomfort by its splinting effect. In case of immediate fitting, a pylon prosthesis is then added by the surgeon and the prosthetist while the patient is still on the operating table. The device is in parts, uses coupling devices, and can be adjusted both immediately and subsequently for alignment and length. In case of early fitting, rather than immediate, the prosthesis is applied 10 to 14 days after surgery, when the operative dressing is first changed and the skin sutures are removed. If no complications are present at that time and the condition of the stump is satisfactory, an elastic plaster mold is immediately taken of the stump for attachment to the pylon, and a tight plaster dressing is reapplied to maintain shape.

Use of these forms of total contact prosthesis as soon as possible after amputation creates an increased proprioceptive sense and utilizes the phantom sensation present. The properly snug application of the elastic plaster of Paris is essential to either method. Subsequent treatment continues with general strengthening exercises to the other extremities, stump conditioning exercises, and training in ambulation with the new prosthesis.

It must be emphasized that success in early prosthesis application depends on the proper and secure attachment of the muscles and fascia to or over the bone end, so as to afford good stump control.

As with lower extremity amputation, upper extremity loss needs also to be treated in a positive approach by the provision of an appropriate prosthesis and training in its use.

In the management of children who are amputees, the restored function and cosmesis afforded by a prosthesis are of practical and psychological value to both the child and his parents. Data from recent studies have indicated that a significant percentage of child amputees with malignancies survive 1 to 5 years postoperatively and wear their

prostheses successfully for a year or longer, the majority of them full time. Delay in prosthetic restoration, therefore, is unjustifiable since the expenditure of time and money involved is vindicated by the rehabilitation results.[12b] Successful independent ambulation may be accomplished by a 3 year old even following a hemipelvectomy if a proper prosthesis is provided (Fig. 5).

For the interscapulothoracic amputation of the upper extremity, the earliest and most useful prosthesis which is to be recommended is a

Figure 5. A, Three year old child with hemipelvectomy. B, Hemipelvectomy prosthesis for the child. C, The ambulatory child wearing the hemipelvectomy prosthesis.

shoulder cap cosmetic prosthesis to support the clothing on the ampu-tated side and to provide the patient with symmetry in appearance. Little can be said for any form of functional prosthesis after this type of opera-tive procedure, as it is too difficult to anchor the prosthesis on the cone of the chest wall because of rotation and displacement when either traction or pressure is exerted. However, a purely cosmetic full-arm-and-hand prosthesis of light weight and good appearance may be provided for those patients desiring it. A shoulder disarticulation does not so radically dis-turb stability and in such cases a prosthesis can be functionally useful.

Depending upon residual stump lengths of the upper extremity, progressively better prostheses can be made, proportional to the amount of stump available. Immediately after operation, the upper extremity amputee should begin occupational therapy for training in dexterity, techniques of one-handed activities in daily living, and strengthening exercises for the stump to maintain its maximal activity potential. This training should continue after fitting of the prosthesis, with emphasis then on the use of the new replacement appliance.

For lower extremity amputees, prostheses of functional value may be provided for patients with any amputation from a maximum of hemi-corporectomy to a residual stump at any level. Amputations of the lower extremities in growing children are more frequently done at the knee or intercondylar level in an effort to retain the distal epiphysis and thus preserve growth potential.

CANCER OF THE BREAST

The most common site of cancer in women is the breast. Treatment is usually by radical mastectomy with or without radiation therapy. Rehabilitation may occasionally be started before surgery, but it usually begins postoperatively due to the fact that the establishment of diag-nosis accompanies the operative procedure. Rehabilitation has three main goals: restoration of external appearance, maintenance of range of motion and function in the operated arm and shoulder, and aid in psycho-logical adjustment. The patient's severe reactions of disappointment, depression, anxiety, and fear require support, reassurance, and encour-agement from the surgeon, the rehabilitation team, and the family.[126, 129] The patient must be instructed in the performance of early routine exercises in the preservation and restoration of function, and she should be given an appropriate prosthesis as early as possible in order to provide for symmetry in appearance and some balance.

In an effort to answer the many questions which arise postopera-tively in the patient's mind regarding her new situation and fears, a small 16 rpm record has been devised by Dr. Guy Robbins of Memorial Hospital to be given to the patient a few days after surgery. This recording is of an informal panel discussion between three mastectomy patients, a nurse, and a physician. She may play and replay it to herself to obtain answers to her own questions and problems. This avoids embarrassment for the patient and saves much time for the doctor.

The early institution of a rehabilitation program after surgery assures best results in restoring physical function and preventing frozen

shoulder. Postoperative dressings and positioning should keep the arm in abduction and slight elevation. Early exercises of the forearm and hand assist in the control of edema and the improvement of general circulation. If the therapeutic approach is by radiation therapy, skin reactions are now seldom seen and related complications of paresthesia or lymphedema develop late. Axillary web formation in the scar is now infrequently seen, with the surgical technique keeping the incision line out of the axilla itself. Should such a web develop, the patient may well need a plastic repair for release.

Approximately 50 per cent of mastectomy patients experience some degree of postoperative arm edema on the operated side. There is marked variation in the areas of the arm which become involved, in the time of initial occurrence of the edema, and in its persistence. Slight swelling which may occur in the early postoperative period most frequently subsides. Swelling which occurs weeks or months after surgery is more likely to be persistent or progressive. Lymphedema disability is proportional to edema extent and the disfigurement it creates. It may be a late sequel due to fibrosis in subcutaneous tissues following supervoltage radiation therapy and occurring a year or more following the institution of this therapy.

Lymphedema treatment has been varied. The use of salt-free diets, diuretics, mechanical aids for massage with intermittent compression, elastic sleeves, and surgical procedures have all been tried. The intermittent compression must be frequent and daily to be in any way effective. Dr. Harry Goldsmith at Memorial Hospital has recently had encouraging success with the control of postmastectomy lymphedema by the transposition of the partially detached omentum beneath the superficial tissues of the chest wall to the axilla and upper arm.[5]

In the prevention of lymphedema, infection must be meticulously avoided and antibiotics used more liberally, especially if there is any necrosis of the wound margin, fluid beneath the wound flaps or the suggestion of infection in the arm on the operated side. These patients should never be given any form of injections or vaccinations in the arm on the operated side, and they should be warned about the danger of infection in the fingers and hand, for which they should seek immediate care.[3]

An occasional patient may show evidence of an underlying psychological instability and inability to face reality; these will require psychiatric advice and therapy. The necessity to advise a young patient to avoid pregnancy and occasionally of the advisability of castration must be presented to the patient with sympathetic understanding and careful explanation. Group therapy provides additional motivation and understanding for these patients.

CANCER OF THE BOWEL

The creation of a colostomy, following resection of bowel for cancer, leaves the patient with loss of voluntary control of elimination. Ileostomy is less frequently performed, but an ileal conduit bladder with its stoma is more often created. Each type of stoma requires different techniques of care in addition to rehabilitation assistance.

Colostomy may develop great adjustment problems for the patient. There may be periods of leakage, noisy expulsion of gas, and odor, with resultant anxiety and embarrassment and often marked social withdrawal. The time consumed to care for a colostomy, and to a lesser degree the other stomas, may demand a change in the patient's and his family's routine and timetable. Varying degrees of dietary change may be required for a few patients. Loss of sexual function occurs in about 50 per cent of male patients after abdominoperineal resection of the rectum. Many patients report a reduced ability to work; they often change jobs, and some stop work completely. Travel, especially by air, becomes more difficult, as the changes in pressure are sufficient to increase gas expulsion and bowel activity.

Rehabilitation is of great importance to these patients and should start whenever possible during the preoperative stage so as to give appropriate reassurance and advanced knowledge to help lessen the shock of finding the artificial stoma. Attempts also should be made to prevent other early postoperative distressing experiences for the patient such as massive evacuation and soiling. The latter can be effected in the operating room by inclusion in the immediate postoperative dressing of a disposable plastic collecting bag unit.

Continuity of care should be provided daily by the same nurse, trained especially in colostomy handling. It is important to select the method of colostomy care best suited to each patient. Management is generally better by irrigation than by the less frequent nonirrigation technique. For management by irrigation a regular "enema" using a catheter with a special colostomy cover and leadoff apparatus, or the simpler bulb syringe technique, is usually administered. Commercially made enemas and evacuant suppositories are not consistently satisfactory.[12f]

The first irrigation, because of its great impact, must be done under the best circumstances by an expert and in private with ample time and sympathetic understanding. A toilet or commode should be used, unless the patient must remain lying in bed. As the patient's strength increases he is taught to take over increasing amounts of daily care, until he assumes complete care and has given himself several irrigations before leaving the hospital.

The nonirrigation technique is not widely used, but may have merit where toilet facilities are not satisfactory, where no regulation has been accomplished after trial of the irrigation method, or where debility, handicap, or old age would make any other procedure impossible.

Prior to discharge from the hospital, the surgeon should discuss home plans with the family so that when the patient reaches home adequate preparations can have been made and needed equipment secured. A visiting nurse may be called in to give a helping hand during the first few days at home to thus eliminate some concern and confusion. Further assistance can be obtained from a visit with another patient who has successfully lived with a colostomy and mastered its care. Some help may also be obtained from "ostomy" clubs.

Regular follow-up facilities should be provided for all patients, as problems may arise and functional changes occur, such as stricture at

some level of the stoma. The latter may require local surgical revision to restore adequate functioning.

CANCERS OF THE FACE AND MOUTH

The treatment of cancers of the face and mouth may be followed by severe cosmetic problems as well as functional defects in speech, mastication, swallowing, and salivary control. Resection of the tongue may also result in difficulties in speech and swallowing. Enucleation of an eye creates a reduction in total visual field and change in the accuracy of depth perception, as well as need for cosmetic prosthetic replacement. Successful radical orofacial surgical procedures have increased the number of patients and their extent of facial disfigurement.

Because of the physical area of disfigurement, it is extremely difficult for the patient to mask or hide his problem, and this can create severe psychological problems, greater in many ways than the problems from the physical deficit itself. Rehabilitative care should start ideally in the preoperative period and should include counselling of the patient and the family, in close communication and cooperation with the surgeon. The patient should be informed of the type of surgery planned and of the expected result in order to assist him in long-term planning.

Surgical procedures of several stages are often necessary for these patients and there are tedious waiting periods. Rehabilitation can be greatly assisted by supplying from the surgical and dental team either a temporary or a permanent maxillofacial prosthesis, functional if possible, to lessen disfigurement and restore all possible useful activity. Reconstructive plastic surgery requires patience and understanding on the part of the patient himself and the team rendering him care and support.[12"]

Social service should work extensively with the patient and the family. Speech therapy can assist the patient in overcoming a great portion of his disability in speech production. Vocational counselling should be obtained to encourage the patient, arrange for continuation of his regular job, or retrain him if necessary in a new field of work. Every effort should be directed to prevent the patient from adopting an attitude of social withdrawal.

CANCER OF THE LARYNX

Cancer of the larynx treated by total laryngectomy results in loss of speech, entailing a major deficit in communication. Speech training becomes the most pressing need in rehabilitation, either through the development of esophageal speech or with the use of an artificial larynx. Esophageal speech is a preferred method for it is much more satisfactory than a prosthetic appliance insofar as articulation, intelligibility, and phonation are concerned, and it can be successfully taught in the majority of cases. Poor communication by comparison follows with any form of buccal speech or whispering.

Prior to surgery, the patient should be advised that the expected loss of speech will be temporary and that there will also be a temporary loss of taste, which will return as he learns to talk. In the immediate postopera-

tive period and until he has learned to talk, the patient should communicate by writing and signs and thus avoid development of bad communication habits, facial grimacing, and whispering. The importance of correct instruction cannot be overemphasized. Only a trained speech therapist or another laryngectomee, a successful speaker, should undertake this training. If such a trained instructor is not available in the patient's home area, then the patient should travel to the nearest center. Preoperative speech training and the ability to "belch" are not related to success in becoming an esophageal speaker. It is generally felt that active speech instruction should start at about the time of discharge from the hospital. It is also valuable at the time of discharge to provide each patient with a postlaryngectomy kit containing the main essentials required for good care: a tracheotomy tube, gauze, Vaseline, a bib, a shower cover, and saline or Zephiran in saline.[12a]

Social service and vocational training play large rehabilitation roles. Training for change in occupation may be necessary, especially if previous employment required verbal communication or exposure to fumes, dusts, or underwater work. The patient and the family require instruction in the care of the stoma, the use of the bib, and general hygienic care.

RADICAL NECK DISSECTION

Radical neck dissection results in both cosmetic defect and disability in the shoulder on the operated side, secondary to section of the accessory nerve. The patient develops varying degrees of trapezius muscle paralysis with a dropped painful shoulder and a rotated scapula, depending on the amount of primary innervation carried to the trapezius by the accessory nerve.

Treatment requires support of the arm and shoulder initially with a sling, to prevent overstretching of the trapezius, and an exercise program to include strengthening and conscious utilization of the rhomboids and levator scapulae for training in movements to facilitate abduction of the arm at the shoulder. A certain number of patients with direct innervation of the upper trapezius by cervical roots will retain function lost by the others. In "preventive" surgical rehabilitation of patients, attempts have been made to use nerve grafts to replace the removed segment of the accessory nerve. The greater auricular nerve can be used for this purpose. Reports of results are varied, but it is considered worthy of trial, if the operative opportunity presents easily for the surgeon concerned. During the healing following this procedure, muscle stimulation electrically may be beneficial. Use of supportive fascial slings and muscle transplant of the levator scapulae have also been considered.

These patients should also be taught to support the shoulder and upper arm when seated, on a chair arm or pillow, in order to prevent stretching of the trapezius. A booklet for instruction in exercises, similar to that given to breast patients, is now distributed to patients by the Head and Neck Service at Memorial Hospital.

CANCER OF THE LUNG

The rehabilitative measures concerned with cancer of the lung entail consideration of the effects created by thoracotomy and associated

procedures. There may be postoperative restriction of pulmonary function, furthered by bandaging as well as pain; decreased respiratory reserve depending upon the amount of lung tissue removed; and impairment of the mechanics of breathing due to chest wall resection.

The rehabilitation program should include preoperative training in breathing control and proper coughing technique, taught to the patient as early as possible to promote understanding of directions and to create familiarity of the patient with the chest team. These procedures prior to surgery can assist in clearing the tracheobronchial tree of undesirable secretions. Breathing exercises include segmental control, especially of the basal segments, for aid in ventilation as well as in expansion. Proper posture is stressed. Effective coughing is taught by correct control of respiration rather than by force or volume of expelled air. Activity of the accessory musculature of the chest, neck, and back is reduced to minimize discomfort. Manual splinting of the chest assisted by the patient helps to reduce both discomfort and apprehension.

Techniques of chest percussion and shaking are not added for the early postoperative patient, because of the presence of the wound. If postural drainage is ordered, it should be continued until the cough is nonproductive and the patient is ambulatory.

Non-vigorous exercises of the arms, trunk and lower extremities are taught starting on the first postoperative day for the purpose of restoring or maintaining full range of motion, strength, and circulation in the extremities, especially on the operated side.[6]

CENTRAL AND PERIPHERAL NERVOUS SYSTEM TUMOR INVOLVEMENT

Malignancies, whether primary or metastatic, involving the brain, spinal cord, and peripheral nerves create motor and sensory deficits and affect coordination. Treatment for the patient should begin as soon as the disability is diagnosed or the surgery completed. The entire spectrum of plegias and peripheral neuropathies may be encountered. The general treatment is the same as the standard recognized care program for such disabilities unrelated to cancer.

Focal neuropathy may result from the excision or transection of a major nerve. Treatment consists of range of motion exercises for the affected extremity and, if an arm, provision of a sling for support to limit subluxation and pain at the shoulder. A tenodesis splint or ADL splint may answer an individual need, when the loss has been that of function in a dominant upper extremity. Special exercise and practice in the unilateral use of the normal arm and hand are especially important. In lower extremity unilateral paralysis, bracing with a long or short leg brace, depending upon the need, may render the patient ambulatory. Muscle re-education should be carried out when there is any evidence of reinnervation either functionally or by electrodiagnostic testing.

In addition to the use of steroids and radiation therapy, control of persistent pain may require a neurosurgical approach. Procedures include nerve block, rhizotomy, cordotomy, medullary tractotomy, thala-

motomy, and lobotomy. Hypophysectomy or adrenalectomy may be useful, especially in the presence of breast carcinoma with multiple metastases. Unfortunately, after cordotomies, which are usually bilateral when pain is persistent, the pain may recur even though there is residual cutaneous anesthesia. The lobotomy procedures are done more for anxiety relief than for relief of pain per se.

Causalgia and paresthesia are occasionally helped by the application of hot packs or cold packs and by gentle massage. It has been recommended in some centers that for the persistent case of causalgia, without known etiology or therapeutic response, the use of hypnosis administered by an accredited hypnotist may be helpful.[11]

Problems related to sensory losses are not amenable to direct therapy. The patient can be assisted, however, by training and substitution of other sensory modalities, or other patterns of activity, to minimize the effect of the loss. Impairment of motor coordination may be improved by special training.

LEUKEMIA, THE LYMPHOMAS, AND HODGKIN'S DISEASE

The lymphomas, either during treatment or after therapeutic control, may leave the patient with residual weakness and diminished tolerance for stress and fatigue. With these as well as with metastatic carcinomas of other origin, pathological fractures may threaten or occur. These require appropriate orthopedic and radiation therapy. Depending then upon the individual disability and tolerance, treatment begins with active range of motion exercises and later, if the patient is able to participate, training and assistance in ambulation with appropriate supports to mobilize him. Otherwise, a goal of wheelchair mobilization should be sought.

REMOTE EFFECTS OF CANCER ON THE NERVOUS SYSTEM

Remote effects of cancer on the nervous system produce varying clinical syndromes of neuromyopathy. Symptoms may develop after those of the neoplasm, or they may precede other evidence of the neoplastic disease. Muscular weakness and wasting occur, with weakness most frequently in the limb girdle and proximal muscles rather than distally. Pain may accompany the weakness. There is a striking tendency for symptoms to remit for long or short periods without regard to the course of the tumor or its treatment.[1] Therefore, it is important to teach the patient exercises as preventive measures against the effects of disuse and lack of range of motion.

Coupled with the remote effects of cancer on the nervous system and the muscles are similar effects of medications such as the steroids and the cancer chemotherapeutic agents. Supervoltage radiation therapy, also, may create malfunction in the nervous system. Peripheral nerve dysfunction tends to be late in appearance and may not occur until a year or longer after the radiation therapy has been administered, whereas effects on the central nervous system are earlier and are directly related to the degree of change within the cell of the central nervous system itself.

Table 1. *Patient Distribution According to Treatment Goal at Onset of Care, October 1965 to October 1968*

Patient Total	1237
Goal	
Restorative	398
Supportive	478
Palliative	288
None (No Rx)	73

TREATMENT EVALUATION

On admission to the rehabilitation program each patient is classified in accordance with expected treatment goals. Factors considered are: cancer diagnosis and state of disease, presence or absence of known metastases, age, occupation, health history, other disease diagnoses, x-ray and laboratory determinations, and the findings on physical examination. 1237 in-patients (Table 1) have now been seen during the initial 3 years of the cooperative rehabilitation project at Memorial Center. The peak of distribution has been in the group classified for a supportive goal, with progress of disease and effect of disability being kept under at least temporary control. Many patients could only expect palliation as the

Table 2. *Distribution of Patients According to Length of Time Treated (502 Completed)*

Days

1 -	27		
2 -	16		
3 -	17	123	266 (2 weeks)
4 -	11		
5 -	26		
6 -	26		
7-10 -	95	143	
11-13 -	45		

399 (1 month)

Weeks

to 3 -	75	133 (3-4 weeks)
4 -	58	
5 -	41	
6 -	23	103 (over 1 month)
7 -	15	
8 -	6	
9+-	18	

Table 3. *Evaluation by Grade of Response. Unselected Patients*
with Cancer-Related Disability (1019 Patients)

Grade	Number	Legend
0	211	No change or improvement
1	110	Slight improvement, marked disability
2	320	Moderate improvement and appropriate response to rehabilitation care, residual disability
3	270	Marked improvement, residual disability
4	108	Fully independent, no residual disability
	1019	

result of care. Patients classified with a restorative goal were considered to have excellent potential for cancer control and for return to independence for either appreciable or indefinite periods. A small number of patients were not accepted for treatment because of individual findings or complications or because of refusal of care.

The character of a cancer hospital such as Memorial Center is essentially that of an acute care hospital. Length of time available for provision of a rehabilitation medicine program has ranged from 1 day to several weeks (Table 2). Of the first 502 patients treated, half were given rehabilitation treatment for up to 2 weeks, and four out of five received care for less than 1 month. One in five was hospitalized long enough to receive treatment for over 30 days.

Evaluation of response to rehabilitation care was made with consideration of disease status, age, total handicap, and work or activity outlook, as background for the physical response. Grades were given numerical values from 0 to 4, as listed in Table 3. The response of the individual case and the total evaluation according to groups and classifications of goals indicated appreciable benefit derived by the majority of these unselected patients.

Persons needing further rehabilitation following discharge were treated as out-patients at the Institute of Rehabilitation Medicine. Occasional transfers were effected from Memorial Hospital to the Institute, when necessary, for provision of intensive rehabilitation care. The evaluation of the responses in this group of patients gave results similar to the in-patient population.

PSYCHOSOCIAL AND VOCATIONAL PROBLEMS

The patient with cancer may develop great psychological problems. Anxiety results from the fear of prolonged suffering, mutilation, and

death. The individual patient is likely to relate his problem and his future to what he has learned from others with cancer diagnosis. He may fear being unwanted or considered different by friends or family, and may be so distressed as to attempt complete withdrawal.

An effort must be made to gain the support of the family to promote the patient's participation in social activities and work. Help can be obtained from religious advisors and mutual assistance groups, such as the "ostomy clubs" and laryngectomy and mastectomy groups. Social service personnel can direct in assisting and understanding these needs.

The cost of hospital, surgical, and rehabilitation care overburdens most budgets. Community resources should be fully utilized by families and offered by those concerned with the care of the patient, before shortage of funds has created financial hardship and delay in complete care and rehabilitation.[9, 10]

A vocational outlook is important to the patient who may otherwise fear that because of his illness his family will have to make sacrifices of such things as his children's education, recreation, and needed clothing. The vocational counselor will aid immensely here to help in motivation of the patient toward rehabilitation and work. Not to be overlooked by vocational rehabilitation services is the patient with a limited work expectancy who has hope for at least temporary employment. Common sense will dictate plans commensurate with the prognosis rather than elimination of the patient as ineligible.[11] The majority of patients referred in the rehabilitation program at Memorial Hospital have been in the employable age group.

CONCLUSION

It is essential to establish early medical staff recognition of patient disability and of rehabilitation potential and to stimulate prompt referral for rehabilitation care. Rehabilitation therapy early in the period of disability will eliminate development of periods of hopelessness, frustration, and despair. Preoperative training and counsel for the patient about to undergo surgery will add both psychological and physiological benefits.

Disability from cancer or its treatment can be considered by the same criteria as are used for disabilities not connected with cancer. Goals for restorative and supportive care can be set, and there is need for rehabilitation care in the form of palliative assistance for the patient with incurable and even terminal cancer.

No accurate judgment of life expectancy or the length of time for engaging in useful activities can be estimated for a patient with cancer, in spite of the general tables available. Therefore it is unrealistic and contrary to good rehabilitation practice to defer the provision of rehabilitation services for a waiting period in order to determine the status of the disease or the question of its spread.

It would be a great service for the cancer patient if we would change our current basic appraisal or concept of the results of cancer treatment from that of "cure" to that of "control." Analogous to tuberculosis, recurrent disease at the original or another site is always a possibility and after "control" the patient may be returned to a relatively normal life.

Such consideration would also eliminate the unfortunate problems created by an arbitrary time limit of 2 or 5 years in consideration of eligibility of a cancer patient for a positive rehabilitation program.

Social service can remove otherwise insurmountable obstacles, and vocational rehabilitation should be employed even in the case of limited life expectancy, if, by so doing, the patient may again become temporarily employed or return to maintenance of a home situation, such as that of a mother with children. Each patient should be considered on an individual basis, with evaluation of the medical findings, the prognosis, and maximum eventual gain to the patient, his family, and the community. Comprehensive medical care will then have been provided for that patient.

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Clinical Neurophysiology in the Evaluation of "Weakness"

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Weakness is one of the most common subjective complaints encountered in clinical practice, and at the same time is a symptom whose significance is most difficult to assess. Semantics contributes to the problem, since "weakness" may mean listlessness or fatigue to one person, while to another it may connote loss of muscle strength or asthenia. In general, it may be said that asthenia is more likely to be associated with serious disease than lassitude, or lack of energy, which is frequently a psychosomatic manifestation.

The differential diagnosis of a disease involving weakness as one of a patient's presenting complaints requires the same approach as evaluation of any other medical entity; it is primarily dependent on careful history and physical examination complemented by pertinent laboratory studies. The use of electrophysiologic techniques falls into such an adjunct category.

The complaint of weakness which is acute in onset does not pose so great a problem, since it is usually part of a readily identified symptom complex, as occurs in acute infectious disease, hemorrhage, etc. It is with the more chronic diseases, frequently with vague onset, that most of the difficulty arises. Table 1 presents examples of various categories of disease and organ system lesions in which weakness may be a dominant symptom. It is obvious that electrophysiologic tests will be of no value in the study of many of these disorders; on the other hand, considerable assistance in diagnosis may be rendered in others. This report is concerned with representative examples in the latter category.

INFECTIOUS DISEASES

The differentiation of infectious polyneuritis (Guillain-Barré disease) from poliomyelitis by clinical means is sometimes quite difficult. Results

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Table 1.   *Diseases in which Weakness May be a Cardinal Symptom*

Infectious Diseases	*Myopathy*
Tuberculosis	Progressive muscular dystrophy
Brucellosis	Thyroid myopathy
Parasitic diseases	Myasthenia gravis
Hematopoietic Diseases	Myotonia
Severe anemia	Familial periodic paralysis
Toxic Diseases	*Neuropathy*
Uremia	Localized lesions:
Heavy metal poisoning	Peripheral nerves
Botulinum toxin	Roots
Alcoholism	Spinal cord
Neoplasms	Brain
Myopathy or neuropathy secondary to	Generalized
carcinomatosis	Chronic motor neuron disease
Metabolic and Endocrine Diseases	Charcot-Marie-Tooth disease
Thyrotoxicosis	Dejerine-Sottas disease
Diabetes	Polyneuropathy of various etiologies
Porphyria	*Collagen Diseases*
Glycogen/lipid storage disease	Rheumatoid arthritis
Psychoneurosis or Psychosis	Dermatomyositis/polymyositis
Hysterical paralysis	Periarteritis nodosa

of cerebrospinal fluid examination are often equivocal. Since a major difference in the pathology of the two diseases involves a neuronal (cell body) lesion in polio, while there is frequently a severe axonal component in polyneuritis, impairment of impulse conduction in the affected nerves is observed in the latter. The conduction velocity of motor fibers in mixed peripheral nerves may be determined in a well established and reliable manner. It is not unusual for the motor conduction of the median nerve in the forearm of the patient with neuritis to be slowed to 20 meters per second. By comparison a normal conduction velocity of 53 meters per second may be anticipated in the patient with polio (Fig. 1).

ENDOCRINE AND METABOLIC DISEASE

While motor nerve fiber conduction delays may be encountered in infectious diseases, most of these defects are encountered as part of localized compressive neuropathies. Trauma is the most frequent cause of these entrapments, but there are some which reflect underlying systemic disease. The median nerve is involved under such circumstances. This nerve passes into the hand from the forearm through a fibro-osseous tunnel whose floor and sides are formed by the carpal bones and whose roof is the tough transverse carpal ligament. Any lesion in this closed space, the carpal tunnel, results in extrinsic compression of the nerve.[3] Tuberculosis, Boeck's sarcoid, and osteochondroma, are examples of etiologic factors. In the category of endocrinopathy, hypothyroidism with even mild to moderate myxedema is attended by a high incidence of the carpal tunnel syndrome.

Characteristically the conduction velocity of the median nerve in the forearm is normal while the impulse conduction time of the segment of the nerve at the wrist is prolonged. The interval between the beginning

of the stimulating electrical shock and the evoked muscle action potential is called the latency. An acceptable normal mean value for the median nerve is 3.5 to 4.5 milliseconds (msec). In the patient with compression, a typically abnormal value may range from 5.5 to 10.0 msec. It is worth emphasizing that the conduction defect of the nerve is a limited, segmental one. In diabetic neuropathy, by contrast, so much more of the peripheral nerve axis is affected that the conduction velocity in the forearm may be reduced to 40 meters per second, with a concomitant delay across the wrist of perhaps 6.0 msec. A deficiency in conduction in sensory nerve fibers is frequently observed in diabetics; in fact, the electrical changes may be recorded before there is clinical recognition of the metabolic defect. Figure 2 presents the method

S = STIMULATING ELECTRODES
R = RECORDING ELECTRODES
A P B = ABDUCTOR POLLICIS BREVIS
M = MEDIAN NERVE

D = DISTANCE FROM ELBOW TO WRIST POSITION
OF STIMULATING CATHODE
E = EARTH CONNECTION

B   POLIO   D = 25

C   POLYNEURITIS   D = 24

S_a = ARTIFACT PRODUCED BY ELECTRICAL STIMULUS
t_1, t_2 = TIME BETWEEN ONSET OF SHOCK AND RESPONSE
M = EVOKED MUSCLE ACTION POTENTIAL
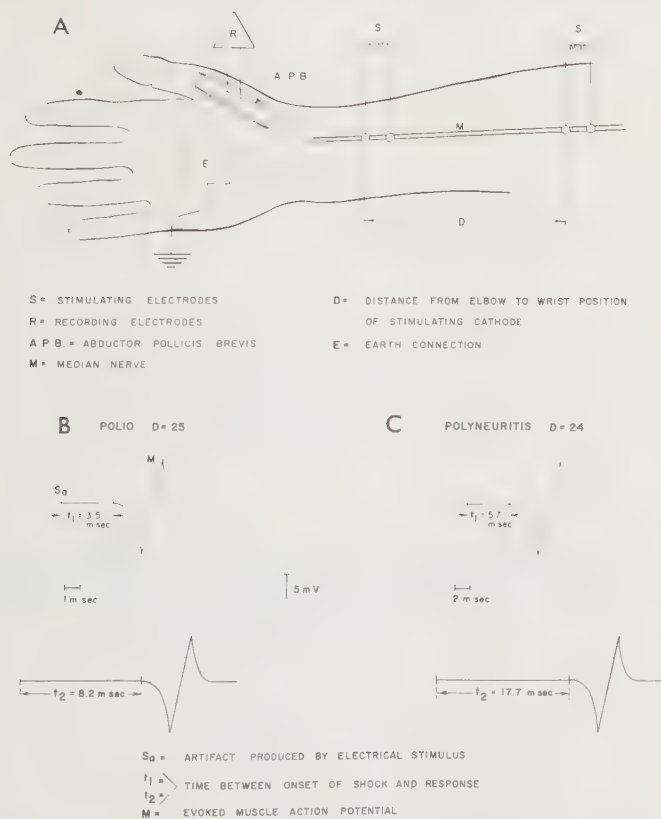
Figure 1.   Recording conduction in motor fibers. A, Diagram of method to record motor conduction velocity of the median nerve in the forearm. Stimulation is made at two percutaneous points along the nerve, at elbow and wrist. The recording electrodes are placed on the thenar eminence over the belly of the abductor pollicis brevis. The distance D between the two sites of stimulation is measured along the surface of the forearm. B and C. Oscilloscopic recordings in patients with polio and polyneuritis, respectively. The time required to traverse the distance D is equal to $(t_2 - t_1)$. Conduction velocity (CV) = Distance/Time. In polio, the CV = $\dfrac{25 \text{ cm.}}{(8.2 - 3.5) \text{ msec.}}$ = 53 meters per sec. In the patient with polyneuritis, CV = $\dfrac{24 \text{ cm.}}{(17.7 - 5.7) \text{ msec.}}$ = 20 meters per sec.

2 A   S = RING ELECTRODES PLACED AROUND DIGIT TO STIMULATE DIGITAL NERVES

       R = RECORDING ELECTRODES PLACED OVER MEDIAN NERVE AT WRIST

2 B   Sₐ = SHOCK ARTIFACT

      S N A.P. = EVOKED SENSORY NERVE ACTION POTENTIAL
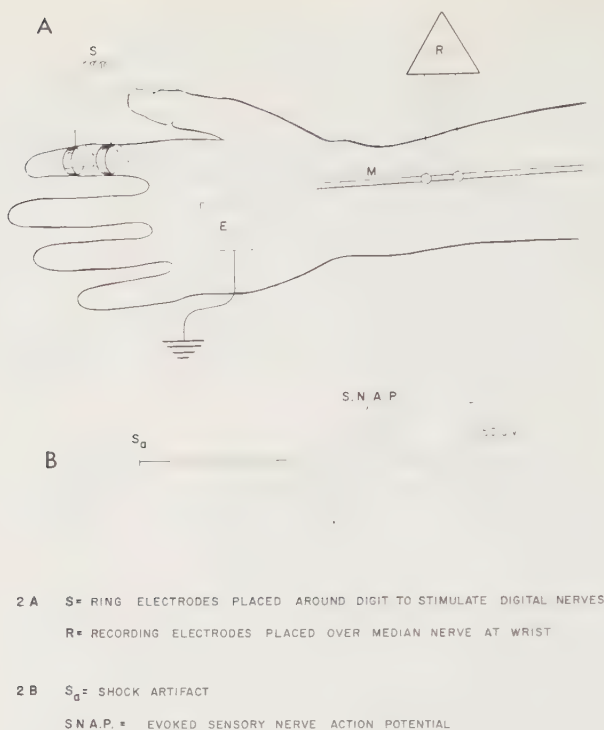
Figure 2.   Recording sensory nerve action potential. Sensitivity of the instrumentation must be considerably improved to record the voltages of sensory nerve action potentials, which range from 10 to 50 microvolts as compared to the 5 to 10 millivolt range of the muscle action potential. *A*, Placement of electrodes. *B*, Recording of a sensory action potential from the median nerve at the wrist after stimulating the digital nerves of the index finger.

required in studying conduction in these sensory nerves. In compression of the median nerve at the wrist in the carpal tunnel syndrome, the earliest abnormal electrophysiologic changes may also involve sensory fibers. The alteration in both diseases may present itself as a delay in the latency of response of the sensory nerve action potential, an attenuation of the amplitude, or, as is so frequent, an absence of response to electrical stimulation; a sensory nerve action potential cannot be evoked.

MYOPATHY

In the primary myopathies there are no abnormalities of peripheral nerve conduction velocity (a block at the neuromuscular junction, is, of course a cardinal feature of myasthenia gravis).[1,4] The primary muscle diseases are distinguished by characteristic electromyographic patterns consisting of changes in amplitude, duration, and configuration of the muscle action potentials as well as some distinct differences in rate of discharges of the motor units in response to gradation of voluntary contraction. Typically, in myopathy the motor unit potentials are of lower amplitude and shorter duration than normal. The incidence of poly-

phasic (more than four peaks) muscle action potentials is considerably increased. With small or moderate effort the frequency of firing and the total number of motor units discharging is greater than normal. In pseudohypertrophic muscular dystrophy, these EMG features may be observed. The myopathy secondary to hyperthyroidism cannot be specifically identified, but there is one highly significant consideration: it is curable!

Myotonia may be considered with the myopathies and is characterized by an inability to relax the contracted muscle. The group includes myotonia congenita, myotonia dystrophica, and paramyotonia. Electromyographic recordings in these patients show long trains of muscle action potentials which oscillate in both amplitude and frequency. Subjectively, the myotonia is frequently less impressive to the patient than is the accompanying weakness. Recently a patient was referred for study of weakness; the referring diagnosis was diabetic neuropathy. Electromyographic studies showed findings typical of myotonia dystrophica. In retrospective clinical examination, myotonia could be observed and elicited by percussion.

Within the field of internal medicine, paramyotonia may hold more interest since there is a link between myotonia and a specific disturbance of potassium metabolism – hyperkalemic periodic paralysis. Adynamia episodica hereditaria has been identified as the same disease. Recently the occurrence of myotonia has been reported in familial periodic paralysis of the hypokalemic type.

It is of interest to note that recently we have prepared an animal model of myotonia dystrophica by daily injection of 25-azacholesterol over a period of 3 to 5 weeks.[²] Electromyographic recordings are indistinguishable from those of the human disease (Fig. 3).
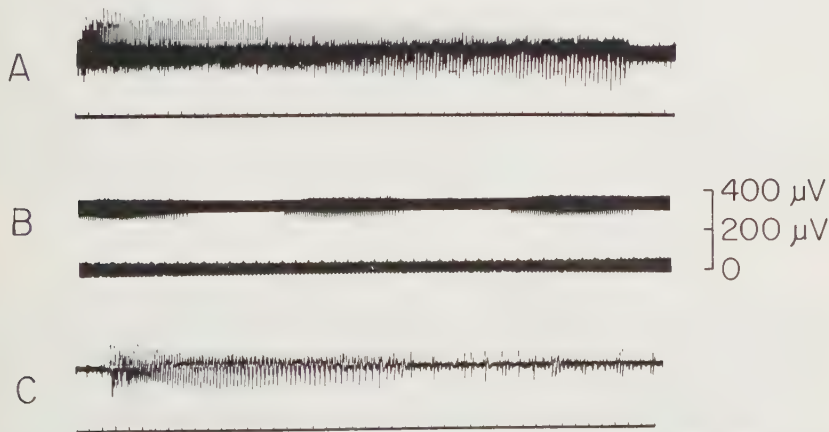
Figure 3. Myotonic discharges recorded at various sweep speeds in a Wistar rat in whom disease was induced by administration of 25-azacholesterol. Note oscillations of amplitude and frequency. A, B, and C are tracings recorded from the same muscle but at different sweep speeds so that the variations in frequency and amplitude may be easily observed.

NEUROPATHY

Primary neuropathy with axonal pathology shows both nerve con- duction and electromyographic abnormalities. This is the case in Charcot-Marie-Tooth disease. Chronic motor neuron disease is a typical primary neuropathy which can be usually distinguished by electromyo- graphic examination. Conduction defect is rarely seen and usually only in the severe terminal state. The occurrence of abnormal spontaneous discharges, called fibrillation potentials, is much more typical of neurop- athy than of myopathy, although these do occur but less frequently in the latter. Fasciculation action potentials are never seen in myopathy. Since motor neurons are destroyed (polio, amyotrophic lateral sclerosis). maximal volitional activity can only involve less than a normal comple- ment of active motor units. This is in sharp contrast to the observation of the response in primary muscle disease, where small to moderate contraction involves maximum frequency and number of discharging motor units.

NEOPLASM

Electrophysiologic studies in the patient with neoplastic disease may show evidence of local or systemic involvement. In generalized carcinomatosis, both neuropathic (including severe nerve conduction changes) and myopathic electromyographic patterns occur. In localized carcinoma, the lesion may cause segmental block of conduction. For example, an osteochondroma of a carpal bone may cause signs and symptoms of carpal tunnel disease, and an early Pancoast's tumor of the lung may present neuropathic findings identified by electromyography as abnormalities occurring in a plexus distribution. A special case is made for the small cell carcinoma of the lung, which may be associated with a myasthenic syndrome of profound weakness.' By means of elec- trophysiologic studies the myasthenia associated with bronchiogenic carcinoma (frequently occult!) may be differentiated from myasthenia gravis by observation of muscle responses to repetitive stimulation of the nerve before and after a period of tetanization (i.e., exercise) (Fig. 4). The myasthenia response, then, is not pathognomonic of myasthenia gravis. To a degree, it may also be observed in old cases of polio, some peripheral neuropathies, and occasionally in chronic motor neuron disease.

COLLAGEN DISEASES

Of the diseases of the supportive tissues, polymyositis presents the most characteristic electrophysiologic findings. On a basic level, poly- myositis may be differentiated from polyneuritis, since conduction velocity is normal in myositis and abnormal in the neuropathy. In addi- tion, on electromyography the polymyositic muscle usually shows a profusion of abnormal spontaneous activity as well as muscle action potentials usually identified with myopathy — short duration motor units,
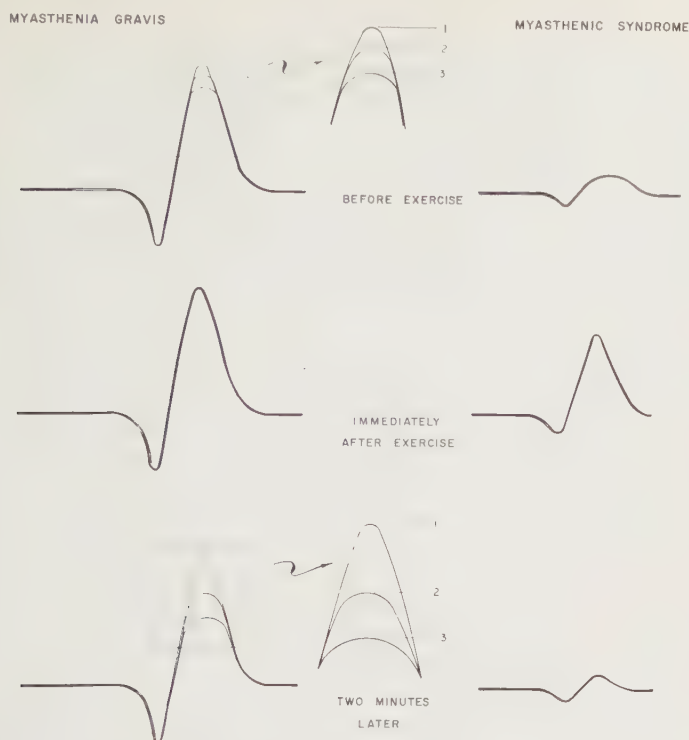
Figure 4. Studies in patients with myasthenia gravis are shown in the left-hand column. *At the top*, Three superimposed tracings with stimulation at 3 per sec. There is a moderate diminishing amplitude. *Center*, Immediately after exercise there is an increase in amplitude (post-tetanic facilitation). *Bottom*, 2 minutes later, the original defect is accentuated (post-tetanic exhaustion).

In the right-hand column are tracings of the patient with small cell carcinoma of the lung. The initial potentials are extremely small. After exercise the post-tetanic facilitation and then the exhaustion are profound compared to those of myasthenia gravis.

and a preponderance of short duration polyphasic action potentials. The incidence of polymyositis during childhood and its associations with neoplasm in the adult are well documented.

SUMMARY

Electrophysical study may render assistance in (1) objective substantiation of a clinical diagnosis; (2) augmentation of the evaluation and prognosis of a disease by quantification—i.e., conduction velocity studies; (3) differentiation of almost indistinguishable clinical pictures— i.e., polymyositis vs. polyneuritis; and (4) demonstration of an unsuspected neuropathy or myopathy which may be primary or related to a systemic disease—for example, observation of a myasthenic muscle response in a patient with an occult oat cell carcinoma of the lung.

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Movement Disorders

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Movement, as such, has been studied in relation to an infinity of factors ranging from basic biomechanical changes producing the contraction of myofibrils to the psychologic and behavioral basis of complex motor performance. Attempting to understand all the physiologic events involved in such action would be impossible. Indeed, present knowledge leaves gaps that can be bridged only with assumptions, speculations, or intuition

TYPES OF NORMAL MOVEMENT

To better explain some of the dyskinetic characteristics one must broaden the concept of voluntary, voluntary automatic, automatic, reflex, involuntary, and purposeful movements. We shall not define these terms in a rigid description but rather relate them to other factors, such as conscious awareness of the movement in question, functional purpose of movement, prior ability to perform it, and temporal and spatial verification of correctness of movement – or, in other words, degree of specificity of goals.

Voluntary movement implies kinetic activity where concept, execution, and completion are willingly and consciously controlled. In general, this type of movement has a clear and well-defined goal.

Voluntary automatic movement differs in that the initiation is voluntary and is consciously undertaken, but control and verification of exactness of intermediate steps is left to subcortical structures, without constant conscious awareness of it; however, without any interruption one can add conscious (cortical) control to the activity.

Automatic movements are usually of association and, in general, comprise skeletomuscular arrangements necessary to perform complex functional activity, and, if so desired, they can be modified or abolished.

Reflex and involuntary movements have in common the fact that neither is the result of a willing, specific desire. They differ in that the former is usually confined to one muscle group and most often preceded

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by an external sensorial stimulation, involving a rather simple neuronal arch. The latter may involve extensive muscle groups, is occasionally preceded by no sensory stimulation, or, if so, by stimulation of proprioceptors from within, and often involves extensive neuronal circuits including cerebellar and cerebral structures. This group can be further classified according to when it appears (rest, intention), what parts it involves (chorea, torticollis), and whether it is rhythmic or not (tremor, flapping).

A purposeful movement is basically a voluntary movement with a strong element of finality and functional motivation.

To illustrate these apparent subtle differences one could analyze the events that occur in walking, a learned, skillful motor activity. This is an activity acquired through a period of learning (usually in childhood) during which very complex visual, kinetic, and postural relationships are established. Let us assume now that a person who is about to walk is standing and no obstacles are blocking his path. The moment he decides to walk he is undertaking a voluntary movement whose concept and execution is willingly and consciously controlled. He may choose to initiate his march with either foot and follow any given course he prefers. Once under way, there is a certain rhythm and cadence in the taking of every step and in the accompanying arm swinging. These well-executed movements, however, are not thought out consciously but take place automatically and in orderliness. Contraction or relaxation of certain muscle groups precedes or follows contraction or relaxation of other muscle groups at a given time and in a given sequence to obtain a forward displacement of the body, keeping good balance and following a predetermined course. This cadent, automatic activity, voluntarily undertaken, can be influenced, modified, or even stopped at will, throughout its performance.

Arm swinging is also an automatic activity, perhaps more so than the translation of the body over a pathway, since by itself it does not propulse but is an associated activity which takes place only with walking or running. As a true automatic movement, arm swinging during gait can be voluntarily suppressed, exaggerated, or performed in an ipsilateral fashion, as opposed to the normal contralateral alternating way.

During the execution of a voluntary automatic movement, such as walking, one can intercalate, at will, modifications necessary to maintain an established course or to avoid obstacles and changes in the horizontal plane of the terrain.

NEUROCIRCUITRY OF MOVEMENT

Since all elements comprised in the execution of movement are interconnected and subjected to control via feedback mechanisms, it becomes difficult to select a given point to start the study of this circuit-like system. For convenience and brevity, one can think in terms of two major centers of activity; there is a central net of circuitry, mainly concerned with the elaboration of the proper signals to act upon a peripheral effector of contractile elements that can pivot or exert forces upon the

osseous structures of the body; this, in turn, will result in the realization of the desired goal, whether it is ambulation, posture, maintaining balance, or reaching for objects. The second center, or effector, has also an information recruiting system that sends signals back to the different areas that elaborated the primary orders to confirm the exactness with which they were performed. It also contains a special system to dampen great oscillations in the intensity of muscle contraction and maintain appropriate muscle tone to the mechanical needs in terms of intensity, speed of contraction, and gravity.

In the study of motor behavior and mind, many parallels can be drawn from observations made in the field of linguistics because of the similarity in the background integration of speech and movement, especially a voluntary movement such as walking. At times, however, the line between purely somatic and psychic qualifications becomes unprecise.

K. S. Lashley[7] summed up this complex neural activity as "the logical and orderly arrangement of thought and action" and postulated that all the input in this neural mechanism is "never fed into a static system but always into a system which is already actively exacted and organized." The interplay between input and this background of activity is behavior.

Figure 1. Schematic diagram of integration of movement. *CC*, Cerebral cortex. *CN*, Caudate nucleus. *Put*, Putamen. *GP*, Globus pallidus. *TH*, Thalamus. *VL*, *PVL*, *CM*, Ventrolateral, posteroventrolateral and center median nuclei. *sn*, Substantia nigra. *stn*, Subthalamic nuclei. *RN*, Red nucleus. *Cbll*, Cerebellum. *o*, Olive. *vn*, Vestibular nucleus. *M*, Mesencephalic nuclei. *rf*, Reticular formation. *P*, Pyramidal tract. *A*, Ascending spinal tracts. *MS*, Muscle spindle. *M*, Muscle. *R*, Rainshaw cell. *LMN*, Lower motor neuron. (In collaboration with Daniel S. Sax, M.D.)
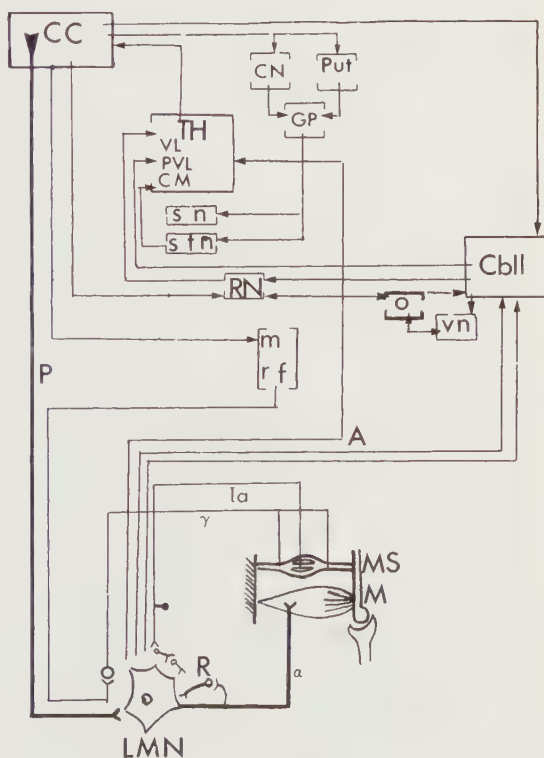
The constant action of networks of neurons capable, in one case, of polarizing the direction of action and, in another case, of discharging bursts of rhythmic excitation, forms the foundation on which every other neuronal activity is elaborated.

This combined activity results in volleys of signals that travel to the effector neuromuscular assemblies via different pathways while being subjected to facilatory and inhibitory influences from connections established in their course, modifying and modulating the original discharges in an adequate manner.

The anatomic location of these structures is rather well recognized, and in many instances their specific function is also known, so it is possible to correlate certain phases of integration with topographic levels (Fig. 1).

SYNAPTIC BIOCHEMISTRY

The integration of neural activity presupposes the transmission of excitation from one neural cell to other neural cells across a synaptic bridge by means of chemical substances that are released and destroyed in extremely short periods of time. The harmonious blending of theories explaining the neurochemical basis of cerebral activity with those interpreting the total integrated functional activity will stand destructive criticism or a purely pragmatic acceptance.

A theory that provides plausible explanations for how cerebral amines function, with relative simplicity, has been recently advanced by De Whurst.[1] Without going into details as to how the theory was developed, suffice it to say that cerebral amines can be divided according to cerebral actions into two distinct and opposing categories: type A and type C, the former having an exciting action and the latter a depressing one. In addition, there is a third group, type B, made up of three different substances that act first on type A and then on type C receptors. The exciting, type A, amines produce mood elevation and aggressive behavior at the same time that they increase motor activity. Type C amines have an opposite effect. These changes can be seen in EMG and EEG recordings.

The relationship between mood and general motor activity is well known, and it is possible to extrapolate observations from mood alterations into movement disorders, and, perhaps, the catatonic states or the agitated phases of mania can be considered as psychologic and motor aspects of specific types of behavior. Some forms of depression illness are caused by a deficiency of type A amines or insensitivity of the type A receptors, and some forms of mania are caused by an excess of type A amines or increased sensitivity of the type A receptors.

The actual mechanism of the behavioral effects is not well known, but some evidence points toward an effect on the synaptic transmission, especially of the dendritic tree, either delaying the synaptic activation or facilitating the crossing.[6]

Inhibitory action in cerebral synaptic transmission using compounds chemically related to cerebral amines (DMPEA) has been

obtained experimentally,[11] as has a reversal of this action when chlor-promazine in small doses was administered. If the destruction of DMPEA is prevented by previous administration of monoamine oxidase inhibitors, even longer delays in transmission result.

Another interesting observation of the relationship between cerebral amines and motor activity is the marked improvement in muscle tone and reflex activity of mongoloid infants receiving 5-hydroxytryptophan (5-HTP), a precursor of serotonin (5-HT).[2]

Some movement disorders of cerebral origin can be caused by deficiencies in extremely potent amines, metabolites or enzymes that also have powerful effects in other tissues and organs, but in some conditions only symptoms referable to one anatomic location are visible, without widespread systemic effects. In the concrete case of the brain, this possibility could be readily explained if we consider[8] that changes in the permeability of the blood-brain barrier or increases in metabolic rate in localized cerebral areas may result in a much lower concentration of vital substances in the brain than in the blood. The increase in metabolic rate may be due to a special great concentration of enzymes in certain nuclei and, conversely, a decrease in metabolic rate may be by virtue of a reverse process.

In summing up, one can visualize the integration mechanism of the brain as a constant excitation and discharge of its network with refractory periods, following this discharge, that interfere with connecting circuits in such a way that arriving impulses reorganize the established pattern. New impulses acting upon a neuron may not be strong enough to cause its firing, but may modify excitability to stimuli coming later and in this manner facilitate the discharge of a combination of cells. This combination or arrangement of "facilitated" neurons may be visualized as a "primed" circuit which will respond jointly to external stimuli.

The "facilitation" or "refractory" periods created by subthreshold impulses are also present at the distal end of the motor pathway and the local excitatory status of the anterior horn cell is nothing but the sum of all the impulses reaching it.[5]

The concept of constantly active, dynamic, interconnected systems in which temporal order and dependent sequence is the "modus operandi" offers in our opinion a workable ground to understand motor behavior as an integrated activity and, also, to explain some of its pathologic aspects.

PARKINSONISM

The parkinsonian syndrome is so protean in its presentation that within the same diagnostic category one includes patients whose clinical appearance, progression, and response to medical management are totally different. Therefore setting uniform regimens of medication, physical therapy, or surgical intervention for these patients will fail to result in similar degrees of improvement.

In the physiatric evaluation of the parkinsonian, it is of prime importance to distinguish and separate signs and symptoms that are

strictly neurologic in origin from those disabling manifestations that are secondary to the neurologic process. This distinction is fundamental if one is to estimate with some accuracy what and how much is amenable to treatment and consequently which aspects of the entire problem can be improved.

As a general rule, the purely neurologic symptoms are not affected by physical therapy; hence, tremor and rigidity, the two more common and outstanding, do not respond to such measures.

Patients with long-standing parkinsonism will be apt to show great diminution of their functional abilities in all motor activities, especially in ambulation and related areas. It is in these cases where the separation between neurologic and biomechanical causes has to be made clear and, especially, the recognition of bradykinesia has to be made in order to construct a truly effective plan of therapy.

In considering the biomechanical changes responsible for their faulty posture, poor balance, and difficulty in ambulation, one should analyze the anatomical imbalances that take place when the parkinsonian patient assumes the erect position.[9] These deviations can be summarized as: (1) neck flexion, (2) kyphosis of the dorsal spine, (3) flexion of elbows or wrists, (4) hip flexion, (5) knee flexion, (6) ankle plantar flexion with heels off the ground, and (7) body weight bearing on heads of metatarsal bones and toes. This posture modifies normal stance in the following manner.

The base area, which normally is outlined by the lateral margin of both feet and the lines connecting the toes anteriorly and the heels posteriorly, becomes greatly reduced when the patient lifts his heels off the ground. Consequently, his balance becomes less stable, and he will show a tendency to shorten the swing phase of his gait; hence, the short and quick steps so characteristic in parkinsonism ("marche a petit-pas").

Plantar flexion at the ankle level upon elevation of the heels off the ground interferes with the synergistic action of the ankle flexors and dorsiflexors which control fine adjustments in balance and which also actively participate in supporting the weight of the body.

With the knee maintained in a partly flexed position, no self-locking is possible since the center of this joint remains in front of the hip-ankle line; therefore, in order to keep the body in a standing position, the knee extensors must remain in contraction at all times, with resulting fatigue and impaired balance. Hip flexion is an almost obligatory position whenever there is knee flexion during standing; this contributes to the forward incline of the body which, together with the kyphotic spine, places the projection of the center of gravity slightly ahead of the base area — thus the tendency to propulsive gait.

The position of the arms and the loss of reciprocal alternating movements are additional factors in balance alterations. In the swing phase of normal gait, when the body tends to fall toward the side where the leg is off the ground, the forward motion of the contralateral arm compensates for this temporary imbalance by adding forward momentum to the body and displacing the base area more laterally, away from the swinging leg.

The flexed position of the neck impairs balance and ambulation, not only because of the faulty postural alignment, but also due to the elimination of righting reflexes that normally originate in the cervical muscles and through different pathways (labyrinthine, optic, etc.) facilitate muscle tone adequate to maintain the upright position.

These abnormal postural conditions, even without any additional changes of muscle tone or other neurologic alterations, are sufficient to create a disturbance of the biomechanical pattern needed for standing and walking in a normal fashion.

It becomes important, then, to maintain or improve the existing ranges of motion at the hip, knee, and ankle levels, usually by effective stretching of the hip and knee flexors and of the ankle plantar flexors. Similar corrective procedures are directed towards contractures of the spine to decrease, as much as possible, the kyphotic tendency and, in the cervical area, to stretch the neck flexors and to increase mobility.

During gait training, one tries to apply the same principles in order to enhance proper posture; to avoid the "collapse" of the lower extremities, emphasis is placed on heel strike with full knee extension. This can at times be assisted by forcing the knee posteriorly using strips of cork on the soles of the shoes along the area corresponding to the metatarsal heads.

In the upper extremities, stretching of rotators and adductors to mobilize the shoulder girdle should be done. For the kyphotic tendency of the thoracic and cervical spine, cervical traction in the standing position is useful.

The foregoing procedures are aimed toward correcting the secondary complications which add biomechanical derangements to the basic neurologic disorder.

As previously mentioned, the two outstanding neurologic manifestations, tremor and rigidity, are not correctable with physical therapy. On the other hand, freezing, festination, and bradykinesia occur mainly while performing automatic voluntary movements and can be significantly lessened, though temporarily, if concrete and definite instructions with clear goals are given to patients. Thus, if gait training is the activity to be undertaken, it is best to break down the vague and ill-defined order of "walk" into "take two (or three) long steps," or specify the number of steps to be taken for a certain distance. One tries thereby to accomplish constant volitional (cortical) control for an activity that normally is directed by subcortical centers, thus transforming, insofar as possible, an automatic voluntary movement into a voluntary movement, the basic difficulty underlying freezing, bradykinesia, and festination being due to inability to perform a serial movement in an adequate sequential order. This inability can also be helped by adding external stimuli involving spatial and temporal rhythm. Thus, keeping step to a beat as in march music, or stepping into lines traced on the floor at a distance equivalent to a normal stride, or having to clear small obstacles placed at regular intervals on the floor, will provide the rhythmic and sequential order onto which voluntary activity can be built. This presupposes, of course, undivided attention while engaged in the performance of these sequential acts; distraction or attempting to maintain a conversation simul-

taneously will result in complete default. In activities other than walking, as in getting up from or sitting down into a chair, the approach is similar with decomposition of the total movement into prearranged units, each one in good biomechanical harmony and flow.

It is, also, well to remember that freezing, once it occurs, hardly ever can be overcome through intense, continued effort. It is easier and faster to voluntarily and completely stop the resistance to it and then, after complete cessation, to start again with a definite and immediate goal in mind.

Attempts at developing arm swinging during ambulation do not usually meet with success because no arm swinging takes place normally when walking with very short steps, and if a good deal of attention is placed on the arms, faulty leg motion is most likely to ensue.

A special aspect in the management of parkinsonian patients is the postoperative period following basal ganglion surgery. Without going into details regarding the indications for surgery, suffice it to say that tremor and rigidity can be effectively alleviated by this method. True bradykinesia is not improved, but slowness of movement due to rigidity can be relieved. Complications from surgery are not frequent but range from severe brain dysfunction due to hemorrhage to transient weakness of an apractic nature. However, balance disturbances are frequently seen following surgery. The reason for these may be central (rearrangement of vestibular and labyrinthine signals), peripheral (readjustment to normal muscle tone) or, more probably, a combination of both. The clinical picture of this postoperative balance difficulty is rather constant with leaning of the body to the side for which the surgical procedure was done, a tendency to fall to the same side while standing, and lateral tilt of the head in the same direction. The majority of cases resolve within a few days. In the recalcitrant ones, the situation becomes more difficult to overcome, and consequently treatment is more energetic, consisting of frequent short periods of cervical traction in the standing position, self-correction in front of mirrors, and use of counterweights on the opposite side of the body.

Although the problem of speech and language in parkinsonism is a rather involved one, it is helpful for simplicity to compare the main characteristics of parkinsonian speech with those seen in ambulation, for both activities have in common an element of automatism and learned skill and also show similarities of response according to the order of commands given. Thus blocking, tachylalia, and slurring can be compared to freezing, festination, and short steps. Treatment should, in our opinion, be based on the same general rules applicable to other automatic motor activities; emphasis should be placed on goal definition, rhythm, and use of phonation other than on recognized words in order to reinforce a high degree of volitional component in the execution of complex articulation movements.

Just as many other aspects of the parkinsonian problem cannot be discussed here, pharmacologic management will not be dealt with except to emphasize the importance of a better understanding of the role, synthesis, and metabolism of cerebral amines, since the basic dysfunc-

tion in the process is in essence one of modulation of transmitter substances at synaptic levels. The results obtained to date with L-dopa, although not conclusive, are encouraging. Safer and wider use of these compounds will, no doubt, result in additional means to help these patients.

DYSTONIA MUSCULORUM DEFORMANS

(Torsion Dystonia)

Although the incidence of patients with this disorder is relatively small, they are separately considered here because many of the therapeutic premises pertaining to the dystonic group are applicable to patients with other diagnostic labels but with basic characteristics of "dystonia."

In spite of its relative infrequency, this entity has received attention in the past 10 to 15 years because basal ganglion surgery can be of great help in abolishing the involuntary movements. The success of the latter has brought about renewed awareness of the existence of the condition, and more accurate diagnosis and prompter recognition of new cases has been the result.[1]

Still unpublished results in some of the genetic aspects of torsion dystonia show that, from a hereditary standpoint, two types exist, a dominant and a recessive form. The recessive form, more prevalent among Jewish families, carries with its genetic disturbances a great incidence of high intelligence among those affected.

Aside from its genetic aspects, three main factors clinically need to be kept in mind in the physiatric evaluation of "dystonia."

1. *Gravity.* The role of gravitational pull in triggering dystonic symptoms is so constant that it can be used as a reference point to evaluate progress, severity, and type of involvement. By increasing and concentrating the stress of gravity on a particular area of the body, symptoms otherwise not apparent can be elicited. A typical deformity in dystonia is the so-called "semilunar foot" consisting of marked plantar flexion of the ankle with flexion and internal rotation of the tarsum; this deformity, in the first stages of progression, may be seen only during ambulation or while balancing or tiptoeing with the involved foot while the other leg is off the ground; later on, the standing position alone may be sufficient to evoke the dystonic posture. In the very advanced stages it can be observed even in the horizontal position.

2. *Static and dynamic posture.* In "dystonia," both static and dynamic postures can coexist, and it is important to separate each type from the other; conservative measures, such as physical therapy and splinting, are ineffective in the correction of dynamic dystonia, whereas some improvement can be accomplished in some of the static deformities, especially those in distal parts of the extremities. Here, as with other neurologic disorders, the management of midline symptoms is extremely difficult due to the bilateral central control of axial neuromuscular elements. Long-standing, static postures are apt to become fixed, but it is

advisable not to make irrevocable statements in this regard since, in many instances, following basal ganglion surgery, deformities believed to be fixed disappear in a gratifying way.

3. *Retraining and avoidance.* These constitute two important facets in the management of dystonia, especially in the post-thalamic surgery period. "Dystonia," contrary to many other dyskinetic symptoms, can be overcome by retraining if adequate and progressive patterns of movement are followed. The element of avoidance is intimately related to the understanding of the effects of gravity in this disorder. In other words, the retraining program of muscle control re-education has to be maintained at a level at which the gravitational stress acting upon the part of the body being treated is insufficient to bring about dystonic interference. Only when the gains obtained at a given level have become consolidated is progression to another level indicated. These rules do not only apply to the structure of the therapeutic schedule. In addition, at all other times those positions which induce dystonic activity should be avoided.

TREATMENT. Basal ganglion surgery ventrolateral, ventroposterolateral, center median thalamic nuclei is still one of the treatments of choice in torsion dystonia, especially when conservative measures including varied pharmacologic agents produce little effect.

Orthopedic corrective surgery in the presence of continued dystonic activity does not produce desirable results. Similarly, restrictive bracing and splinting may, occasionally, not only fail to improve the picture but may produce an increase in dystonic activity.

In recent years a peripheral approach has produced encouraging results in patients with symptoms confined to distal parts of the extremities, whether primary or residual to basal ganglion surgery. The combination of peripheral nerve and motor point blocks using alcohol and electrical stimulation to localize the specific area for injection has produced good results. In some cases, the improvement is still present 2 years after the procedure; in others, reinjections 2 to 6 months later have been necessary, the degree of success being probably related to the degree of accuracy in reaching the desired injection targets. At present, we are engaged in the utilization of radiofrequency waves in the creation of lesions to substitute for alcohol and to possibly increase control of the size and site of lesions produced.

Peripheral alcohol blocks have, also, been used in cases of torticollis (a variant of torsion dystonia) in which careful electromyographic studies disclosed which muscles were primarily involved.

CEREBRAL PALSY

The rationale for inclusion of this varied group of patients in this review is similar to that for the inclusion of "dystonic" patients. Indeed, the indications and contraindications for therapy and other procedures follow similar principles. In cerebral palsy, however, there is a unique element in the neurologic picture that poses a prominent factor in its evaluation—namely, the presence of spasticity.

Spasticity may range from severe to minimal, and it may mask the existence of voluntary motor power in the muscles involved. Conversely,

after elimination of the spasticity, it may then become apparent that no voluntary motor power was present under the powerful array of reflex spastic activity. The reduction of spasticity in those cases where there is good evidence of motor power may result in functional improvement. When this evidence, however, cannot be ascertained, the possibility of adding further functional losses by converting the limb or other areas to a flaccid state must be considered. Only where the severity of the spasticity interferes with nursing care or causes irreversible painful contractures may the alleviation of the spasticity alone be a justifiable procedure.

Due to the innumerable causes of cerebral palsy, both etiologic and anatomic, it becomes extremely difficult to generalize on specific treatment procedures. Basal ganglion surgery, for example, may be successful for those patients with minimal spasticity but with considerable tremor or "dystonic" elements. Gross athetoid movements have, also, responded well to thalamic surgery, especially when the simple reduction of involuntary movements represented a functional improvement. By and large, neurosurgical procedures, if effective at all, will reduce or eliminate interfering or excessive muscle tone or movement but will not supply additional strength or increased coordination.

Spastic extremities have been successfully treated in a small series of cerebral palsied children and adults by means of a combination of peripheral nerve and motor point blocks with 60 per cent alcohol.[10] In most cases, this has consisted of a series of injections, usually starting with alcohol blocks of the nerves in the proximal parts of the limb. The block effects a general diminution in the total background spasticity of the extremity being treated and thus permits better evaluation of the distribution of spastic muscles to be subsequently blocked. This technique has, in two cases, resulted in independent ambulation after proper bracing and surgical release of hamstring contractures, and in one case, ambulation with regular canes and an acceptable four-point gait – all in previously nonambulatory patients.

SUMMARY

The inclusion of skill, awareness, and automatism in the definition of movement provides a better understanding of its complex integration. The concept of sequential order and its correlation with synaptic transmission is used in the explanation for certain movement disorders. Finally, three distinct neurologic entities are chosen as therapeutic applications of the previously proposed mechanisms.

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Principles of Medical-Surgical Rehabilitation of the Hand

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The importance of the hand is related to living – to one's future socioeconomic well-being – rather than to matters of life and death. This fact probably explains the apathy concerning disorders of the hand on the part of both the general public and the medical profession. Malignant tumors of the hand are uncommon, and, in the era of antibiotics, lethal infections from the hand are almost unknown; hence, almost no one ever dies as a result of a disorder of the hand. Yet those who have lost functional use of both hands are probably more disabled than anyone else except those with direct brain damage.

World War II was the first major conflict from which we had vast numbers of combatants surviving serious injuries and, therefore, for the first time our colleagues and the country were confronted with large numbers of healthy but physically disabled men. As this group enlarged, the real importance of hand injuries became apparent and during the latter part of the war steps were taken to cope with it. All military personnel with hand injuries were directed to several centers designated by the Surgeon General, and, as one could anticipate, these concerted efforts improved care and pushed progress in treatment greatly ahead. These experiences gave rise to the concept of the hand as an area of regional specialization – the hand surgeon mastering the appropriate aspects of traditional plastic, orthopedic, and neurologic surgical specialization as applied to this small but complex area. Equally as important as the concept of the hand surgeon was the realization that optimal true rehabilitation required carefully coordinated efforts of the surgeon with those of the medical rehabilitation specialist. Unfortunately, much of what was learned in World War II concerning the importance of the hand and its rehabilitation did not carry over into civilian life, despite the

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fact that the hand is involved in so many medical disorders that books have been written about it,[1] and it is by far the most common part of the body involved in accidents.

There is a common denominator for treatment of the hand by the surgeon primarily concerned with the care of the injured hand and the physician dealing with medical afflictions of the hand – *take any necessary steps to prevent extension of the disabilities beyond those resulting directly from the primary disorder.* For the surgeon this implies doing whatever is necessary to assure primary wound healing, infection and secondary wound healing being disastrous and often even precluding successful repairs of injured deep structures to restore function. For the physician, this implies chiefly the prevention of irreversible small joint stiffness whose development compromises the ultimate recovery of the hand, either spontaneous or through reconstructive surgical procedures.

It is not the intent of this paper to discuss functional aspects of the hand or individual disorders comprehensively, but rather to stress and to clarify basic principles of value to the physician in preserving and restoring function to the impaired hand.

SMALL JOINT STIFFNESS – THE FUNDAMENTAL CAUSE OF SECONDARY EXTENSION OF DISABILITIES OF THE HAND

Repeated clinical observations have clearly demonstrated that permanent stiffness of small joints of the hand occurs very rapidly with the triad of persistent edema, inflammation, and immobility in the "position of injury" which the digits invariably assume unless prevented by specific measures (Fig. 1). The understanding of this triad is so fundamental to rational management of the disabled hand that each of these elements merits additional discussion.

Edema

Venous blood and fluids are normally returned from the extremities through veins and lymphatic channels, propelled through these valved conduits by the pumping action of local muscular activity.[6] With immobility of the hand from any cause, as paralysis or even reflexive inhibition of movement because of pain, muscular pumping action is impaired and the part becomes edematous if held at a level below the heart. Edema may be sufficient to reduce arterial blood flow, resulting in hypoxia, which further increases capillary permeability and accumulation of stagnant interstitial fluids in a vicious cycle. The joint capsules and supporting ligaments bathed in these protein-laden fluids are rapidly thickened and become progressively unyielding.

The dorsal skin of the hand, in contrast to that of the volar surface, is very loosely attached and readily distended by the edema. The ballooned dorsal skin pulls the metacarpophalangeal joints of the fingers into hyperextension – a position in which they rapidly become fixed as will be discussed later. In the presence of great edema, the hand cannot
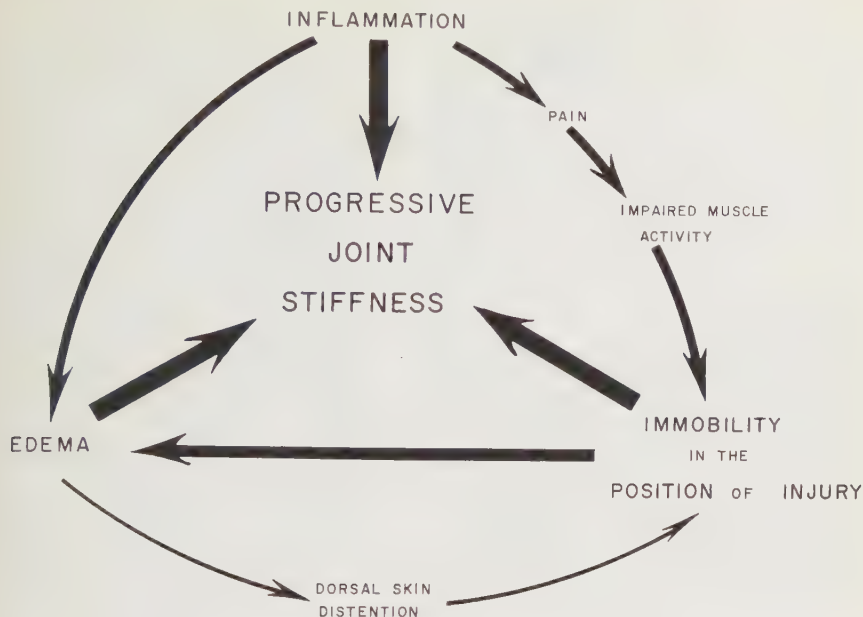
Figure 1.   The triad of inflammation, persistent edema and immobility in a nonfunctional position results in rapid and often permanent fixation of small joints in the hand. Of the factors, inflammation is the most deleterious and also the most difficult to eliminate. Edema is more important than extensor tenodesis action of wrist drop in causing the hand to assume the position of injury, and the whole system evolves into a vicious cycle.

be brought into a functional position for immobilization even though the wrist is fully extended to relax the extensor tendons. Only after reduction of the edema can the metacarpophalangeal joints be brought into flexion.

With impairment of muscular activity of the hand from any cause, edema can be prevented or controlled by continuous elevation of the part above the level of the heart, fluids then being returned by gravity. The heart is the point of reference for elevation. The arm supported by a sling with the hand at the waist is not elevated when the patient is ambulatory – it is simply less dependent than when hanging at the side. However, the hand is effectively elevated in this position when the patient is fully reclined in bed.

Even with effective elevation of the disabled hand, there will be persistent edema if dressings or straps of splints are applied too tightly (Fig. 2). Any such circumferentially constricting devices applying pressure greater than the venous pressure will promote persistent edema. There must be an awareness of how much circumferential constricting pressure can be applied without harmful effects.

By prompt, effective elevation of the disabled hand, avoiding all obstructions to the return of fluids from the part, and encouraging any possible muscular activity, the factor of edema in small joint stiffening can be controlled.

Figure 2.   A, Crushing injury of the arm for which a splint prevented wrist drop, but the splint was fixed to the arm with an elastic bandage. There is poor knowledge of the degree of pressure exerted by these devices, and their circumferential application results in a tourniquet promoting edema.

B, Edema of the hand is always most evident in the loosely attached dorsal tissues. It pulls the metacarpophalangeal joints into hyperextension and is the major cause of the nonfunctional position of this injured hand. Effective elevation will promptly reduce it, if circumferential compression is avoided.

Position of Injury vs. Position of Function

POSITION OF INJURY.   For reasons which are unknown, the injured upper extremity assumes a classical position following even minor injuries. There is cortical release of tone in the muscles of wrist extension, flexion of the elbow, and pronation of the forearm. This phenomenon is seen among animals, as the puppy with an injured paw. Patients with injuries to the hand will appear in casualty departments invariably with the arm in this posture and often strangulating it by grasping the wrist tightly. This postinjury posture is so characteristic that it will be consistently assumed unless specific measures are taken to prevent it. Clinical observations have long borne out that immobilizing the hand in this *position of injury* contributes greatly to rapid stiffening of undamaged small joints. There are basic anatomic reasons for this observation.

When the wrist is acutely flexed, the dorsal skin is tightened and extensor tendons to the fingers are passively brought under tension. By tenodesis action this draws the metacarpophalangeal joints of the fingers into hyperextension, a position in which they are prone to rapid fixation (Fig. 3). With hyperextension of the metacarpophalangeal joints, the mechanism of proximal interphalangeal joint extension becomes ineffective, and the resulting imbalance between extensor and flexor

forces across these joints causes them to fall into acute flexion—a disastrous attitude for their prolonged immobilization. Unlike the metacarpophalangeal joints, fixation of the proximal interphalangeal joints is due to relaxation and folding of the volar plate and deep fascial complex described by Landsmeer.[5]

In addition to the extensor mechanism tenodesis effect on the fingers, the extensor pollicis longus is tightened in the same manner and draws the first metacarpal alongside the second, obliterating the thumb web space and resulting in the functionally disabling adduction contracture of the thumb (Fig. 3). The extensor pollicis longus is the direct antagonist of good thumb position. Awareness of this is especially important in median nerve paralysis where normal opposition to the extensor pollicis longus has been lost. It is on the basis of these effects of wrist flexion that so much emphasis has been placed on the importance of wrist extension for the immobilized hand, and, indeed, simple wrist splinting alone will prevent many of the complications attributable to neglect of the immobile hand. As discussed previously, and again emphasized, massive edema in the dorsal tissue of the hand causes, by skin tightness, exactly the same malpositioning of the hand as wrist flexion does by tenodesis. Therefore wrist positioning in the presence of persistent edema will do little to improve the situation (Fig. 2).

POSITION OF FUNCTION.   No concept has contributed so much to improving care of the hand as that of the *position of function*. It has all the wisdom of parking a balky old car with a weak battery on a hill.[8]

The *position of function*, a term familiar to every medical student, is essentially the reciprocal of the position of injury. To most it means
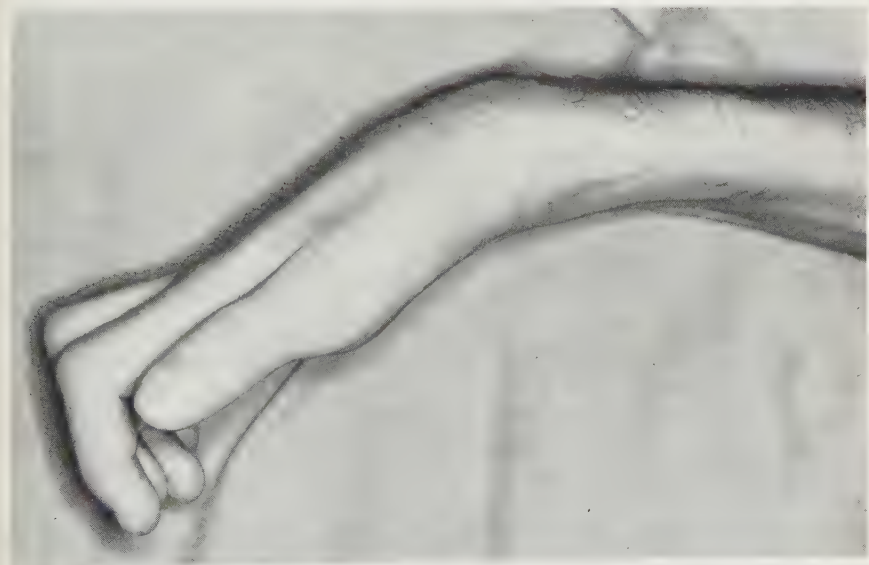
Figure 3.   Position of injury in which small joints of the hand tend toward permanent fixation. There is extension of the metacarpophalangeal joints, acute flexion of the proximal interphalangeal joints, and loss of the thumb web (adduction contracture of the thumb).
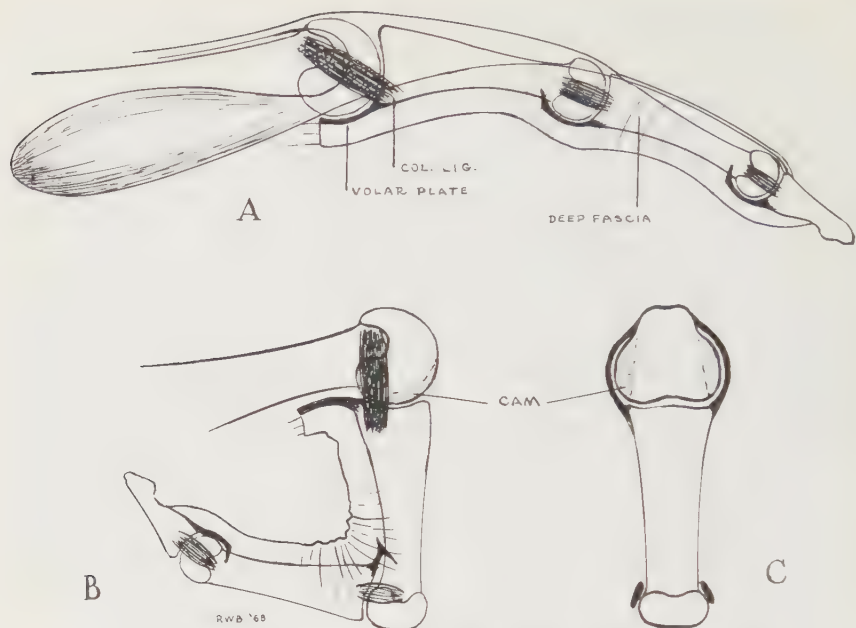
Figure 4. The collateral ligament of the metacarpophalangeal joint is relaxed in extension (A) and stretched in flexion (B), due to the cam action of the eccentric metacarpal head and the pulling of the ligaments around the condyles (C). Thus immobilization of the metacarpophalangeal joints in flexion maintains maximum length of the ligaments.

The proximal interphalangeal joints are prone to rapid fixation in acute flexion due to folding of the deep fascial complex (B) and the volar plate which is firmly attached to the proximal phalanx (A and B). (Note that the volar plate of the metacarpophalangeal joints is not firmly attached to the metacarpal.) In more than 90° flexion, the collateral ligaments of the proximal interphalangeal joint can lock in a very relaxed position along the narrow back of the phalanx behind the condyles (C).

a stereotyped position for the hand, and frequently there is little real understanding of the basis for the clinically proven virtues of this concept. Much of this confusion stems from failure to realize that the same term has been applied indiscriminately to two different situations: one is that of temporary immobilization of the hand in the position in which the least small joint stiffness will occur and the other, the position of greatest usefulness selected for permanent fixation of a joint by arthrodesis. The two may be very different. For example, full extension of the wrist is desirable, though not essential, to the *position of function* for temporary immobilization of the hand. However, this is a poor position for arthrodesis of the wrist, the patient being unable to reach the perineum, put his hand in his pocket, etc.

In the final analysis of the *position of function* for temporary immobilization of the disabled hand, there are three essential features to which all of its virtues can be credited: (1) flexion of the metacarpophalangeal joints of the fingers; (2) extension or only slight flexion of the interphalangeal finger joints; and (3) full palmar abduction of the thumb, keeping the thumb web well stretched.

As pointed out above, wrist extension is desirable. It simplifies maintaining these three essential elements of the position of function, but in itself is not essential to it.

Inflammation

Of the factors in the triad leading to rapid small joint fixation, persistent inflammation is by far the most important and, with rare exceptions, the most difficult to eliminate. The classic example of this is the almost invariable small joint stiffness in the hand resulting from a thermal burn which destroys the skin but does not injure the joints directly. *Whatever the cause, recognition of the paramount role played by inflammation is of the greatest consequence and it is urgent to institute all feasible measures to reduce it as rapidly as possible.* When inflammation is a prominent factor, attention to the other two more controllable factors of the triad, edema and positioning of the hand, takes on even greater importance.

TECHNIQUES OF MEDICAL REHABILITATION

As already emphasized, successful treatment of most injuries and many medical diseases of the hand can be achieved only by the coordinated efforts of surgical and medical rehabilitation. The surgical rehabilitation is effected by the hand surgeon. The medical rehabilitation is achieved by the physiatrist with the help of an all-important team — the physical therapist, the occupational therapist, and the orthotist. In many cases, the aid of a vocational counselor, a social worker, and even a psychiatrist may be essential. It is the purpose of this paper to discuss only the principles of the physical management of the hand.

As stressed in the first part of this article, the most important task of the physician, or, more specifically, the physiatrist, is the maintenance or restoration of the mobility of the small joints of the hand. In order to maintain or restore this mobility, concentrated efforts must be made to reduce edema and inflammation and to maintain proper positioning of the entire upper extremity.

In addition to the key job of securing mobility of the small joints, the rehabilitation team has several other responsibilities. They must protect weak muscles, recent tendon and nerve grafts, and recent fractures and arthrodesed joints. Overstretching of weak muscles can result in irreversible loss of elasticity of muscles. Overuse of weak muscles can result in permanent damage to the muscular fibers so that they cannot function maximally even with return of full innervation. It should be self-evident that recently disrupted tissues must be protected from stress until sufficient healing has occurred.

Therapy must include the re-education of muscles undergoing reinnervation, muscles weak from disuse, and muscles transferred to perform a new function.

Once the above objectives have been realized, the hand may have the necessary physical characteristics for function, but may have insufficient skill to realize its full functional potential. This lack of skill may be due

to long disuse, to poor coordination of reinnervated or transferred muscles, or even to psychological inhibition. Such a hand must be given training to restore functional skill.

Physical Therapy

EXERCISE. *Active exercise is the single most important treatment in rehabilitation.* Exercises are used to regain mobility of joints and strength of muscles and to develop coordination for all movements of the hand.

Many physicians think that it is sufficient after injury or surgery merely to instruct the patient to use the hand as much as possible with no planned rehabilitation except perhaps some initial instruction from the physical therapist. This attitude is a serious mistake, for patients may not use the hand at all through pain or laziness or may develop patterns of substitution that avoid using the weak muscles or stiff joints. Supervised physical therapy and occupational therapy are absolutely essential until the patient can fully control his muscular actions.

At first, when muscles are very weak, the patient may require assistance from the therapist or from supporting equipment. As muscle strength improves, the assistance is progressively decreased until none is required. Then resistance, either by gravity, by the therapist's hand, or by apparatus, is gradually added to the active exercises.

It is often helpful to give the patient simple gadgets to use at home to facilitate his exercises. A hard rubber rectangle, sized and shaped to fit comfortably against the palm of the hand with the proximal edge fitting into the web space of the abducted thumb and the distal edge opposite the proximal phalanges of the fingers, is useful in promoting active flexion of the proximal interphalangeal joints (Fig. 5A). The rectangle blocks flexion of the metacarpophalangeal joints and provides resistance against which the long flexors of the fingers can flex the interphalangeal joints.

Rubber squeeze toys of various sizes, shapes, and resiliencies are helpful in increasing mobility and strength of the fingers (Fig. 5B). Theraplast can be used for similar purposes; it is also helpful in promoting strength and coordination of the intrinsic muscles of the hand (Fig. 5C).

A very simple, inexpensive exercise to increase mobility and strength of the fingers and thumb is provided by nothing more than a wooden dowel, 2 inches in diameter and 8 inches long, and a piece of medium grade sandpaper[2] (Fig. 6A). The uninvolved hand holds the dowel at one end, keeping it stationary; the disabled hand holds the sandpaper wrapped snugly around the other end of the dowel and with alternating rotatory movement of the sandpaper sands the dowel. The diameter of the dowel becomes progressively smaller, demanding more and more flexion and strength of the fingers and thumb.

Another simple and also inexpensive exercise is provided by the use of two ping pong balls[1] (Fig. 6B). The balls are held cupped in the hand and one ball is rotated around the other, first in a clockwise and then in a counterclockwise direction. In the beginning, it may be necessary to

assist the disabled hand by having the opposite hand hold the balls against the palmar surface of the disabled hand, thus permitting the disabled fingers to rotate the balls without dropping them. This exercise requires flexion, extension, abduction, and adduction of all the fingers as well as flexion, extension, and opposition of the thumb.

When muscle paralysis prevents active movement of joints, the maximum range of motion of the joint must be carried out passively by the therapist. The patient or a member of his family should also be instructed to carry out these passive movements several times a day at home.

When stiffness or contractures have been allowed to develop, passive movements and stretching of contracted soft tissues must be carried out with intensity. The additional use of heat, massage, and splints will aid in the remobilization of joints. Stretching, of course, must not be done too soon after repair of tendons or nerves. It must not be done in the presence of articular damage – it will not be effective in correcting the deformity and will only cause more damage to the joint. Stretching also should not be attempted in the presence of significant edema.
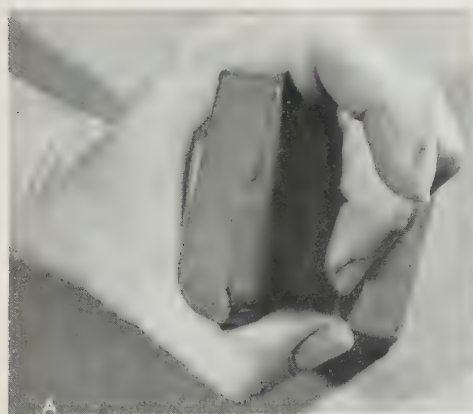
Figure 5.   A, Hard rubber rectangle to block metacarpophalangeal flexion and promote interphalangeal flexion. B, Rubber squeeze toy. C, Theraplast.

Figure 6.   *A*, Sanding of wooden dowel. *B*, Exercise with ping pong balls.

When good rehabilitation is instituted promptly preoperatively and postoperatively, it should be possible to keep contractures of soft tissues to a minimum. When proper rehabilitation is not instituted, the complete function of a hand may be lost.

A word about electrical stimulation is warranted. Its use can be helpful in re-educating muscles that have become reinnervated or muscles that are weak after long periods of disuse or after tendon transfers or repairs. Also, it has been well recognized that the atrophy that results from denervation of muscles can be prevented or significantly retarded by frequent electrical stimulation.[3, 7] Once atrophy has become established, it cannot be abolished by electrical stimulation alone. The use of electrical stimulation to prevent atrophy of numerous muscles in the hand and arm is fraught with impracticalities – it must be carried out at least once daily and it must be done by a trained therapist or by an exceptionally intelligent patient or relative; the former is often prohibitively expensive and the latter usually unsatisfactory.

Heat.   Heat is useful to relieve pain, relax muscular spasm, improve circulation, and soften scar tissue. The value of heat in rehabilitation is to make a subsequent active exercise by the patient or passive movement by the therapist easier.

A warm whirlpool bath is often used to provide heat to the hand and wrist. Unless the patient has sufficiently vigorous active movements of the hand to aid circulation, the whirlpool is undesirable because it keeps the hand in a very dependent position and promotes the formation of edema.

Paraffin is a far more desirable way to heat a hand whose segments are not actively mobile. It can be carried up even to include the elbow.

The use of paraffin has several advantages—its greatest being that the hand can be elevated while being heated. Also, the heat is retained longer, and the condition of the skin is improved by the lubricating effect of the paraffin and oil.

Great care must be taken in the application of heat when sensibility is impaired. The use of heat should be avoided with fresh skin grafts.

MASSAGE.   Massage is of great value in the rehabilitation of hands because of its ability to reduce edema and because of its softening effect upon tissues which have become scarred or fibrosed. Proper massage by a skillful therapist is the best technique available for reducing scarring and adhesions.

SERIAL CASTING.   In attempting to reduce contractures of joints secondary to soft tissue contracture, so often the therapist is able to gain a few degrees of mobility during treatment on one day only to have the patient return the following day with the previous day's gain completely lost. Serial plaster casting then becomes very useful in maintaining the gain which the therapist has made. Each day after gaining a few additional degrees of mobility the therapist applies a thin plaster cast to the joint in its new position of increased mobility (Fig. 7). The gain is then maintained until the patient returns the following day, when the cast is easily soaked off and therapy is given to increase the mobility further.

Figure 7.   A, Flexion contracture of proximal interphalangeal joint of ring finger just prior to treatment by physical therapist. B, Plaster cast applied to same joint shown in A just after treatment by physical therapist.
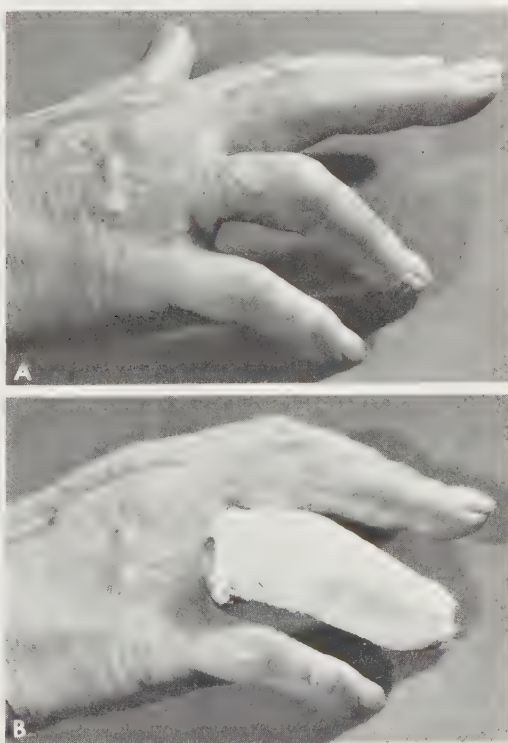
Occupational Therapy

Occupational therapy is essential for the successful rehabilitation of many hands. The occupational therapist provides specific crafts and activities to improve mobility, strength, and function; training in activities of daily living; vocational guidance and prevocational training; and the designing and fabrication of temporary and permanent self-help devices.

Occupational therapy should be started as soon as the state of the hand permits, since active use of the hand is the best therapy in the world and is the only way to reduce pain, edema, decreased mobility, and weakness to a minimum. Also, resumption of functional use of the hand gives a considerable boost to the patient's morale and should be introduced at the earliest possible moment to demonstrate to the patient that the hand can be used. Many patients are afraid to begin to use their hands and have to be given the most vigorous of encouragement to do so. Sometimes one almost has to trick them into doing so.

In the early stages of rehabilitation, when scars are still sensitive, joints painful, and muscles weak, the activities in occupational therapy should be light. Gradually the vigor of activities may be increased and may go on to include the use of heavy tools and various workshop activities.

Orthotic Devices

Based strictly on its Greek derivation the term "orthosis" means "the straightening of a distorted part." In current medical usage, an orthosis is an exoskeletal device to limit or assist motion of one or more segments of the body. Orthoses are valuable adjuncts in the medical and surgical rehabilitation of the hand.

An orthosis assists in the recovery of muscular strength by preventing the persistent overstretching of weak muscles, by preventing the overwork of muscles during the recovery phase and by preventing the development of patterns of substitution which result in the disuse of other muscles.

Orthoses are valuable in the prevention of deformity. Deformities are the result of contracture of muscles and their tendons and of decreased mobility of joints and periarticular tissues. There is just one cause of musculoskeletal deformity—persistent faulty positioning of body segments. This faulty positioning can occur during rest or during activity. The all-important triad of persistent edema, inflammation, and immobility in the "position of injury" has been discussed at length. The other factors that contribute to faulty positioning are weakness, pain, spasm or spasticity, faulty splints, overweight, and pre-existing deformity.

Once a deformity has occurred, an orthosis can be helpful in correcting it. Attempts to correct a deformity are simply a matter of applying force against the deforming factors. Nonsurgical efforts are all too often unsuccessful in correcting deformity; nonetheless, they should be tried. Efforts to correct a deformity must be carried out slowly, gently, and persistently.
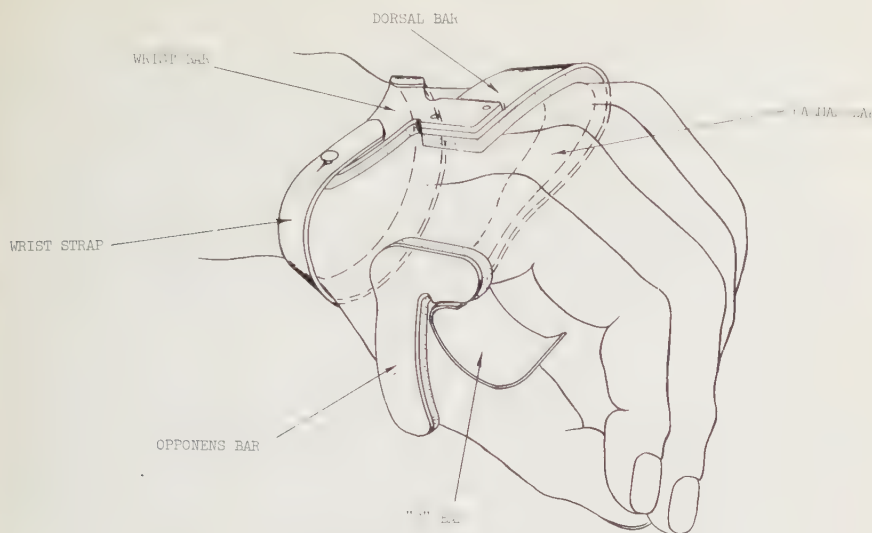
Figure 8. Basic opponens orthosis. This orthosis opposes the thumb to the index and middle fingers. With the "C" bar, it is classically used in median nerve palsies. If there is no muscle imbalance or other factors to produce tightening of the web space of the thumb, the "C" bar can be eliminated. With weakness of the wrist, an extension can be added to this basic orthosis to support the wrist. This basic orthosis can be used to maintain the hand in good position, when weakness is more extensive. This basic splint, with or without a wrist extension, can be modified by the addition of a variety of attachments for specific problems.

Figure 9. Spiral wrist orthosis. This simple, practical orthosis, made of plastic and developed at the Institute of Rehabilitation Medicine, is useful for supporting the wrist in the case of weakness, pain, recent surgery or any other situation requiring support or protection of the wrist. It also prevents ulnar deviation of the wrist. Its unique advantage is that it does not completely encompass the wrist or hand circumferentially at any point. In addition, it has no straps and is easy to apply or remove.

By immobilizing one or more segments of a hand or arm, the use of an orthosis can be helpful in reducing pain and promoting healing in traumatic arthritis, rheumatoid arthritis, tenosynovitis, fractures, lacerations, skin grafts, and postoperative tendon transfers and nerve repairs.

Orthoses are also used to augment function of the hand. Function can be aided by an orthosis prescribed primarily for other reasons during the recovery phase. But in the case of significant, permanent, residual disability, augmentation of function by means of an orthosis becomes the ultimate, definitive goal. Common examples of this goal occur in patients with injury of the cervical spinal cord or brachial plexus who have insufficient preservation or recovery of muscular power to permit surgical reconstruction of the upper extremity.

It is not possible within the scope of this paper to present a comprehensive discussion of all the kinds of orthoses which are useful in the rehabilitation of the hand—they are far too numerous and varied. Two commonly used orthoses are illustrated in Figures 8 and 9.

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Management of the Amputee in Practice

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Many physicians today are faced with increasing numbers of amputees in their practice. Until very recently little was available in the literature on the management of the amputee. Conversely, the need for knowledgeable care has become more acute as the result of advances in medicine and surgery, increased accidents in industry and in automobiles, and the numbers of amputees resulting from military actions. Further, the number of elderly amputees is higher than ever and will continue to go upward as the life span and chronic diseases such as diabetes mellitus and peripheral vascular disease increase.

The spurt in the development of prostheses that came after World War II resulted in greatly improved techniques and devices, so that many more amputees could benefit from prostheses. However, because of the complex problems involved in the restoration of independence, especially with the geriatric amputee, not all patients can be benefited by an artificial limb. This is particularly true if the limb is not suited to the patient's capabilities and specific needs. In fact, if the prosthesis is inadequate, the difficulties and frustrations may be stumbling blocks to independence that might otherwise be possible just with crutches or a wheelchair. While these difficulties are much more often present in an older person, age in itself is not the determining factor in deciding whether or not to prescribe a limb.[1] Since not all amputees can benefit from prostheses, it is important that a patient should never be soothed by a promise of a limb prior to surgery.[3] The physician in caring for his patient must prepare him psychologically for his amputation and rehabilitation, explaining the various phases involved and the possibilities of obtaining and using a prosthesis, thus reducing his anxiety. The patient who knows what to expect will be more cooperative and take an active part in his rehabilitation, participation which is essential for a successful outcome.[5] Casual promises not based on understanding and a

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reasonable estimate of the possibilities can lead to disappointment and misery for both the patient and his family.

Thus, in view of the broadened scope of the problem, the practitioner should know the basic principles governing the current management of the amputee.

SITE OF AMPUTATION

Until the past several years, the goal of surgery was simply to remove a pathological condition. This approach was later modified by the "sites of election" concept (i.e., sites for amputation which were believed to provide the most suitable stumps for prostheses). Advances in prosthetic fitting and manufacturing techniques, however, have now rendered these "sites" more or less unnecessary. Indeed, in many cases, classical surgery is still preferred. The Lisfranc operation is not as effective as surgery through the metatarsophalangeal joints, which preserves a greater weight-bearing surface. The Chopart and Pirigoff operations are performed infrequently; however, the Syme procedure results in a good end-bearing stump.

In below-knee amputations, it should be remembered that circulation around the ankle is normally poor and that surgery should not be performed between the level of the musculotendinous junction of the gastrocnemius and the Syme level. Above-knee surgery can be at various levels—such as the Gritti-Stokes, midthigh, and hip disarticulation procedures. Stumps of various levels can be accommodated in modern prostheses and, therefore, the goal is to preserve as much of the extremity as possible as far as the junction of the Achilles tendon and gastrocnemius muscle.[1] Thus, "elective sites" no longer have the surgical significance of former years.

PREOPERATIVE AND POSTOPERATIVE PHASES

During the preoperative period, while the patient is being prepared psychologically, his medical needs must also be met. Diabetes mellitus must be controlled. The status of the "sound" limb must be evaluated, as well as the condition of the heart. Cardiac decompensation can be a problem, more frequently in older persons, and if severe enough may constitute a contraindication to a prosthesis after surgery.

In the postoperative period the prime concern is avoidance of complications such as hemorrhage, infection, pressure sores, emboli, and pneumonia. After this period, the preprosthetic state begins.

Recently a new technique of immediate postoperative fitting has been developed. While this is promising, it is still experimental. Patients must be carefully chosen and an experienced team including a prosthetist is essential. Immediately following surgery, a rigid dressing is applied to the stump. This prevents edema and allows the patient to bear at least partial weight on a temporary prosthesis in a matter of days. In these cases, the patient can be discharged ambulatory with a permanent prosthesis in 4 to 6 weeks, thus reducing the time necessary

for rehabilitation by several weeks or more. Since this technique, how-ever, has not yet met with unalloyed success, future results will be important in the final judgment.

PREPROSTHETIC CONDITIONING

The preprosthetic phase is the time in which a concerted effort is made to have the patient reach his highest physical and mental level in preparation for the artificial limb. He is given a regimen of therapeutic exercises to strengthen his extremities and trunk, especially the stump. This is done within the limits of the patient's tolerance, with age and cardiac status taken into account.

One of the important aspects of this period of training is range of motion activities, particularly for the stump (i.e., hip and knee for below-knee amputees and the hip for above-knee patients). Contractures about the hip or knee can cause serious problems in prosthetics. The patient with a 20 or 30 degree flexion contracture at the hip or knee will ex-perience extreme difficulty in preventing buckling of the limb; stability will be poor and, especially in an older person, may rule out a prosthesis. Contractures can, on occasion, be stretched out, but prevention is best and is not difficult. Following surgery, the stump should be allowed to remain on a pillow for no more than a few days before active range of motion exercises are begun. Otherwise, contractures can develop quite rapidly.[1] Stump hygiene is also important, and the patient must learn to keep his skin clean.[6, 7] Shrinkage is crucial for proper shaping of the stump and is best accomplished by an elastic stump shrinker.

Learning to walk with crutches is an essential part of the prepros-thetic program, although in older persons a pylon or a walkerette may be used in place of crutches. The patient is also trained to carry out his activities of daily living as independently as possible. Walking with crutches (or a walkerette) with or without a pylon and ability to carry out self-care activities are to some degree indices of a patient's stability, motivation, and potential ability to use an artificial limb.[1]

At this stage of increased activity, cardiac status should be re-assessed. Dyspnea and precordial pain secondary to walking or other physical activity which persist despite appropriate treatment usually are considered contraindications to the use of a prosthesis. A grade IV-E cardiac patient, too, obviously cannot use a limb. These are generally the only conditions which intrinsically constitute absolute contraindi-cations to a prosthesis.

Problems such as hypertension, diabetes mellitus, and peripheral vascular disease should be medically treated. Although there are some who feel that the viability of the remaining limb in cases of peripheral vascular disease is jeopardized by walking with a prosthesis, this has by no means been proved. This school of thought is offset by those who claim that moderate walking helps the circulation of the remaining limb. If the patient uses crutches instead of a limb, his symptomatology may be even worse with resultant debility engendered by a bedfast or wheel-chair existence.

The prescription of a limb thus depends on not only one but rather a combination of factors (except in cases of intractable cardiac decompensation, etc.). Age, stability, motivation, ability to function independently, absence of pain in the remaining limb when walking – all must be considered.[2]

The presence of phantom limb pain or a painful neuroma should also be taken into account and necessary treatment given. While phantom limb sensation is frequent, it is not usually a major problem and usually disappears as the patient increases his activity.[6] If pain is superimposed on this picture (whether central or peripheral in origin), physical therapy measures may help. Painful neuromas can also be difficult to treat and even excision may provide only temporary relief. Injections, tight bandages, and percussion should be tried.

Management of bilateral amputees is a more complex problem. Older persons frequently are not able to learn to use two artificial limbs, especially in the case of bilateral above-knee amputation. If one amputation is below the knee, the situation is much better, and with two below-knee amputations many amputees learn to walk fairly well. However, for these cases, considerable care must be taken in deciding upon the feasibility of a prosthesis.

PRESCRIBING PROSTHESIS

For the patient to be fitted with a limb, the stump must be shrunk as nearly as possible to a conical form so as to permit accurate measurement and maximum confort and fit. This is begun when the stump is healed and is best carried out with an elastic stump shrinker held on by a pelvic belt attachment. If an elastic bandage is used, care must be taken to apply it smoothly with no folds that might produce skin abrasions. If an elastic bandage is improperly applied, circulation problems and a poorly shaped stump may result. Once maximum shrinkage is achieved, the patient can be measured for his prosthesis.

Once it is decided that a patient is a suitable candidate for a limb, selection of its components depends upon his stability, conditions at his place of residence (i.e., stairs or elevator), probable degree of activity, the functional ability of the patient, social and cosmetic factors, and vocational considerations. Based upon these factors, goals for the amputee can then be established. The components thus must be quite specific depending on the precise needs of the patient. Ideally, these decisions should be made by a prosthetic clinic team consisting of the physician, prosthetist, physical therapist, and, as needed, occupational therapist, social worker, psychologist, and vocational counselor.

In view of the comprehensive considerations necessary prior to prescription of a limb, the multifaceted problem is best handled by such a team. Prescription should not be left to a prosthetist alone, who cannot know the medical problems and other limitations of the patient. The team approach is used from the beginning, each member contributing his own special knowledge of the patient. The physician checks the patient medically and generally, and the stump in particular; the physical

therapist is concerned with muscle strength and range of motion, ambulation, and possibly self-care activities; and the prosthetist with materials and components. Jointly, the prosthetic prescription is arrived at. Once delivered, the prosthesis is checked for adherence to prescription, fit, comfort, alignment and cosmetic appearance. Adjustments and revisions may then be requested, and the limb rechecked when these are effected.

Then comes the time for the amputee to be trained in the use of the limb: how to apply and remove it, how to care for it, and, perhaps most essential, the reasons for his returning to the clinic. Follow-up is absolutely essential for good amputee management, for as the limb is worn, the stump may shrink further and change in contour. This will shift weight bearing to areas other than those desired and result in abrasions, pain, and infection. Furthermore, the limb does wear out after a time, and the patient's medical status also needs surveillance. The amputee should, therefore, be rechecked in the clinic at periodic intervals even if he has no complaints.

A detailed discussion of prosthetic components would be out of place in this paper. The practitioner should know that an above-knee limb is composed of a socket, artificial knee, foot and ankle joint assembly, and a method of suspension. Each of these items can be delivered in several varieties and must be chosen for the patient's specific needs. The hip disarticulation prosthesis, similarly, has special sockets and even special limbs. The below-knee prosthesis is the same as the above-knee type but with different suspension mechanisms, different types of sockets, and no artificial knee.[7]

THE UPPER EXTREMITY AMPUTEE

In the case of the upper extremity amputee, the problem is so specialized that it needs to be managed by a physician with special training and experience. Duplication of function of the hand is vastly complex and more difficult than is duplicating the weight bearing function of the lower extremity. The hand is highly specialized with many varieties of functions. Recently there have been many improvements in upper extremity prostheses and much new interesting work is in progress with new types of hooks and hands and new types of control systems – electric, external power, and myoelectric. But these are highly intricate and specialized appliances. While prosthetic devices for the upper extremity amputee can provide a good degree of function, they are still far from satisfactory in terms of fine finger activities and methods of control. It is fortunate that the incidence of upper extremity amputation is less frequent than that of the lower extremity.

SUMMARY

The above general principles of amputee management should thus be known to the physician so that he may advise his patient properly and enable him to obtain optimal treatment. Actual prosthetic management is best accomplished by a team specialized in the area of prosthetics.

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Immediate Postsurgical Fitting of the Lower Extremity Amputee

Research Experience with 175 Cases

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During and shortly after World War II, the military services and the Veterans Administration experienced a surge of new interest in the total rehabilitation of the amputee. The Advisory Committee on Artificial Limbs to the Surgeon General was moved to the National Research Council, National Academy of Sciences. Its Committee on Prosthetics Research and Development, made up of specialists from the military institutions and the Veterans Administration, was joined by personnel from numerous universities in an ongoing program in the design, development, fabrication, and testing of artificial limbs. This group is now affiliated with the University Council on Orthotics and Prosthetics Education and the Committee on Orthotics and Prosthetics Education in an integrated, nationwide, broadly based program that includes postgraduate courses in several universities where thousands of doctors, prosthetists, and therapists have been trained in meeting the needs of amputees. These teaching programs are of short term and concentrate primarily on the prosthetic aspects of the rehabilitation of the amputee.

Until 5 years ago, great progress and improvements had been made in the design, quality, and function of artificial limbs. But progress in amputation surgery was needed to make it possible for amputees to get the most out of these new designs and devices. The relatively modern practice of early mobilization, as applied to the management of many other surgical conditions, did not filter down to amputees. As a group, lower extremity amputees benefitted from this principle only to the extent of achieving earlier use of the remaining leg. There still remained a long preprosthetic program of exercises, wrapping the amputation stump for shrinkage, shaping, and conditioning, all of which took a great deal of time even with good management. The postamputation period

for the great majority of amputees consumed months of supervision, resulting in loss of time and productivity and the deteriorating emotional and physical effects of inactivity and disuse.

Although it had long been known that the amputee could be made ambulatory in a much shorter time than was customary, the implementation of this knowledge was very limited. Isolated efforts on the part of individual doctors to eliminate wasted time were made in military hospitals, and with some success. These included the use of plaster of Paris sockets, pylons, temporary prostheses, and other improvisations with which the amputee could function until he was ready to be fitted with a permanent prosthesis.

In principle, these devices were based upon protecting the amputation stump by concentrating weight on proximal parts. The stump itself was a passive member and often, when not sufficiently protected, showed signs of stress from early use. These devices served a useful purpose by demonstrating that amputees could become ambulatory shortly after surgery, but were restricted to military hospitals or other institutions where a resident prosthetist was available. There was no carryover to civilian amputees, since civilian hospitals were not equipped with specialized facilities or personnel who had sufficient interest to conduct these early efforts at reducing disability time. Moreover, it was customary for commercial prosthetists to take 6 to 18 weeks to deliver a prosthesis. The idea of getting amputees up and walking with double support in a short time remained a challenging dilemma for those interested in the rehabilitation of the amputee.

In July 1963, Dr. Marion A. Weiss, Director of the Rehabilitation Institute of Konstancin, Poland, reported on his procedure of immediate postsurgical fitting and ambulation. On the basis of his convincing evidence, which became well known after he had visited the United States and lectured at numerous medical centers, activity in this procedure spread like brush fire in many countries. Within a year, numerous grants, primarily federal, were made to support serious investigation of this procedure. The Veterans Administration contracted to conduct a full-time research effort at the University of Washington in Seattle, directed by Dr. Ernest M. Burgess, and major research programs were organized at New York University, the University of California, Northwestern University, Duke University, and the United States Naval Hospital in Oakland, California. All of these research projects were closely monitored by the National Research Council and numerous meetings were held with the project directors, who exchanged information on their procedures. Commercial devices became available to meet the need and commercial prosthetists were brought into the program to provide services in the operating room and to deliver prostheses rapidly. From this extensive research, there has emerged a body of knowledge which was sound, practical, and teachable, to the extent that it could be carried out in any well equipped hospital.

EARLY EXPERIENCE

The project at New York University Medical Center, sponsored by the Social and Rehabilitation Service, Department of Health, Education

and Welfare, is just completing its third year and is phasing out of the research stage into routine activity. The objective of this study was to develop this principle for the geriatric amputee, who could benefit most from it.

The Surgical-Prosthetic Group chose to perform a tension myoplasty as the surgical procedure and worked out a satisfactory procedure for creating a well-shaped, relaxed, stable stump padded with shaped muscles and skin flaps drawn together loosely to leave them freely mobile over the end of the amputation stump.

In the early part of this project it became obvious that something was wrong, since more than 50 per cent of the patients had some form of complication, most prominent of which in the older age group was delayed healing or necrosis in the anterior flap. It was recognized that these complications were not due to the procedure, but were possibly due to technique or lack of understanding of what may possibly be taking place in these patients. Therefore an extensive study of wound healing was undertaken and was made somewhat easier by looking back into a study of a thousand patients done at Bellevue Hospital in a research program sponsored by the Vocational Rehabilitation Administration and completed in 1960. Interesting information was developed, resulting in better insight into the selection of patients and procedures. It was obvious that debilitated elderly patients suffered from more than the threat of losing a limb. The normal process of healing, which consists of the development of granulation tissue with the growth of new capillaries and the fibroblastic infiltration of the operated area for the purpose of laying down collagen fibrils in the intercellular ground substance, was being interfered with.

There are three groups of conditions which retard healing and interfere with the normal process.

1. *Infection.* Traumatized tissue, particularly in the presence of vascular impairment, is prone to infection. Devitalized, dead, or infected tissues result in oozing of serum or purulent material, separating wound edges and obstructing the normal healing process.

2. *Mechanical.* Among these are swelling, trauma, foreign bodies, motion, and drying of deep tissues. Swelling is an expected reaction to trauma or surgery, but it may be exaggerated after prolonged or rough surgery, creating tension within the tissues, interfering with fibroblastic activity, and preventing the formation of new capillaries. Hematomas prolong swelling and promote overcongestion of the tissues. Trauma may result from excessive handling of tissues, improper use of instruments, and the crushing of soft tissues while achieving hemostasis. One of the most often overlooked factors causing trauma and delayed healing in amputation stumps is the application of tense sutures. When sutures are tied too tightly, whether they are deep or in the skin, they impair circulation by strangulation of tissue, and their very presence results in excessive reaction and swelling. Foreign bodies usually create excessive tissue reactions. Debris from rough surgery, large suture knots, and sometimes nonabsorbable sutures become isolated and delay healing. Motion will delay healing if the bone within the stump is not stabilized,

muscles are retracting, or skin approximation is inaccurate. Drying of tissues, especially the flaps, will retard healing; they should be protected from the operating room lights and kept moist.

3. *Metabolic*. These consist of dehydration, general debility, malnutrition (particularly with hypoproteinemia), shock, diabetes, low-grade uremia, anuria, cardiac failure, and other forms of anemia. Patients who undergo amputation shortly after taking large doses of steroids have delayed healing. Tissues exposed to x-rays in tumor cases do not heal well or do not heal at all. Patients who are excessively obese with large masses of fat in the tissues are very poor candidates for normal healing.

PRESENT STATUS

In the light of this information, an operative conference was held before each operation to make sure that the medical factors relative to each individual patient were carefully evaluated to the extent that one could anticipate the possibility of delayed healing. From that time on, the results were uniformly better and the complications fewer, because we had developed some insight into the problems of the amputee aside from the local condition requiring amputation.

As of November 1, 1968, 175 cases were completed, in two groups: (1) immediate postsurgical fitting and (2) early ambulation.

In immediate postsurgical fitting, it is deliberately intended to perform a satisfactory amputation and cover this with a contoured surgical dressing, over which a sterile stump sock is applied. On the stump sock, shaped and skived felt pads are glued to protect the patella, the medial flare of the tibia, and the anterior tibial crest in below-knee cases. Thereafter, a plaster cast is applied with the knee in 10 degrees of flexion. The cast extends halfway up the thigh. It is applied at first with the use of elastic plaster of Paris. When this has set, it is reinforced with regular plaster of Paris bandages. The elastic plaster of Paris is so applied that there is proximal pressure (from below upward) at the end of the amputation stump and the method of applying it is such that there is no circular compression of the stump or the thigh. This is extremely important, since it simulates the position of the amputation stump in a total contact prosthetic socket. This is known as the rigid dressing, which is applied whether it is intended to have the patient walk in this socket or not. The rigid dressing is compressive while the plaster is wet, but when it sets, it is no longer compressive but is simply firm, and there is no instance in which the circulation has been embarrassed by a properly applied rigid dressing.

When it is intended for the patient to walk in this socket, a coupling device with steel straps is placed over this cast and with further plaster of Paris bandages is incorporated in the cast. Because the patient has been previously measured for length and alignment, a pylon device can be attached to the coupler. This pylon device terminates in a foot and can be removed for sleeping. If all goes well, it is possible to stand the patient the next day and in the ensuing period, progressively have him

shift weight onto this amputated side and gradually ambulate with partial weight-bearing until he develops stability and confidence. The temporary prosthesis is adjustable for rotation, mediolateral angulation, and length, so that a satisfactory weight-bearing line can be achieved without placing undue stress on the tissues and having the patient distribute weight through every surface of the amputation stump and onto the thigh as well.

Early ambulation is basically the same procedure, with the application of the rigid dressing but without applying the walking device. This does not interfere with the usual procedure of getting the patient up on his unamputated leg, bearing weight and walking between parallel bars or using crutches, in order to preserve and maintain function in that extremity. In 10 to 20 days, the cast and sutures are removed and a temporary prosthesis is applied for ambulation.

TENSION MYOPLASTY TECHNIQUES

In above-knee amputations, the tension myoplasty is performed and the same procedure of application of a rigid dressing is carried out. Some prosthetists prefer to apply this in a manner similar to the formation of a quadrilateral, ischial-gluteal weight-bearing socket. This can be done with casting devices in the operating room, but an experienced prosthetist can also do it by hand. Suspension of this socket to prevent it from coming off when the patient sits up is still a problem not yet solved. Many methods have been employed, and all have resulted in both successes and failures. This is an individual problem resting with the prosthetist who assists the surgeon in the operating room. If the cast becomes loose and begins to slide, it must be removed and another cast applied. This is sometimes carried out three to four times before a removable prosthesis is used.

The tension myoplasty in below-knee cases is performed in a manner similar to the conventional form of amputation, with the addition of suturing all of the cut muscles to the end of the bone and, in many cases, to each other at the end of the bone, but the muscles must be shaped and thinned out distally. In below-knee cases, a long posterior flap of gastrocnemius muscle and its fascia is brought forward covering the entire stump, including the muscles which had previously been sutured down to the bone, and the fascia is attached anteriorly. When the muscles are sutured to the bone, they must be brought down with gentle tension, so that when the patient attempts to move the amputated foot they contract isometrically without having to take up slack. Muscles which are not sutured to the bone will retract. There is great advantage to having these muscles contract with volitional attempts on the part of the patient, since he derives feedback from the tension of the muscles and the contact with the prosthetic socket when he is walking—information which he could not previously obtain and which now makes it possible for him to derive better proprioception and communication with the ground, as well as increased stability and confidence. In addition, the bone is stabilized by this procedure so that it does not move within the

muscles. There is less shrinkage in volume, since the degree of atrophy from disuse is diminished when the muscles contract.

In amputations above the knee, several methods of performing the tension myoplasty are available. In midthigh amputations, the method used at the New York University Medical Center has been to preserve a long tongue of the adductor magnus medially, bringing this over the cut end of the femur and suturing it to the bone. The anterior compartment, consisting of the severed quadriceps muscles, is sutured to the front portion of the adductor magnus and the hamstrings posteriorly. This is all covered by a flap of fascia lata from the lateral side, making a closed envelope for the stump, all being under slight tension and stabilizing the bone in the center of the amputation stump so that it does not move from side to side within the soft tissues. In above-knee amputations nearer to the knee, particularly in the supracondylar region, the long flap is made from the quadriceps group and sutured posteriorly over the entire stump after anchoring the other muscles to the bone.

The procedure of tension myodesis, which was the procedure carried out by Dr. Marion A. Weiss, has essentially been abandoned, although it served an important purpose. This procedure required the use of drill holes in the bones, through which the sutures anchoring the muscles to the bone were placed and knotted in the medullary cavity. This appears to be excessive surgery; it leaves a lot of foreign bodies in the medullary cavity and creates unnecessary trauma in the course of surgery.

The use of a drain when the rigid dressing is applied is a matter of personal choice on the part of the surgeon. A drain was not used in any of the 175 cases at the New York University Medical Center. Infection was present in two cases, but these were both borderline cases where infection was present at surgery distal to the site of amputation. The reason that a drain is not used has been previously stated, namely the rigid dressing prevents swelling and also prevents the formation of hematoma because of the snug fit when properly applied. In our cases it was rare to find more than a blood stain in the dressing after removing the cast 2 weeks later.

POSTOPERATIVE CARE

Whether or not the patient walks, the cast is removed in 14 days for the purpose of removing the skin sutures. At that time, the prosthetist should be available to the surgeon for the purpose of applying two casts. The first cast is removed for the purpose of making a plastic socket for a temporary prosthesis. The second cast is immediately applied and left on to prevent swelling of the tissues. It has been the common experience among the investigators of this procedure that upon removal of the first cast, if the stump is not covered with another cast within an hour, it swells to the extent that the opportunity has been lost to proceed with this activity without complication. Even though this second cast may remain on for only a day or two, for the purpose of being fitted with a plastic socket which can be removed at night, this cast should be applied. The patient is provided with either another temporary leg with a plaster

of Paris socket for a period of time, or he can go into the plastic leg. When he removes the leg, he applies an elastic shrinking sock, in which he sleeps, to prevent swelling when the rigid cast is removed.

The patient is then trained with his temporary removable prosthesis, but with an adjustable pylon, in order to make certain that proper alignment and a correct weight-bearing line are preserved. Adjustment will be required in the course of time, since some shrinkage will occur and some points of pressure will develop. These must be immediately relieved in order to avoid trauma to the amputation stump. By the end of 3 weeks, the tendency to swell disappears and the patient may then use the limb with a high degree of comfort. It has been our procedure to allow the patient to wear his temporary limb for 2 months before being fitted with a permanent prosthesis. Although we fitted many patients with permanent prostheses in the third, fourth, or fifth week, too many physiologic changes take place in the amputation stump for the socket to continue to fit well for any prolonged period and it may have to be replaced.

We do not permit our patients to bear full weight on an amputation stump before the sixth week, even if they can do so comfortably. They are instructed to use crutches and place only part of the weight on the amputation stump, not more than 50 per cent until the sixth week. Instances of late necrosis, breakdown, and evidence of stress have been seen in a great many patients who, because of a full sense of comfort and independence, applied too much weight on the prosthesis before the tissues were ready to tolerate it. Although this procedure has changed the timing of function for amputees, it has not changed the physiologic processes, and firm healing and stabilization of the tissue does not take place any sooner with this procedure than with any other.

LEVELS OF AMPUTATION: RECONSIDERATIONS

In the selection for the level of amputation, some consideration must be given to the reason for amputation, as it relates to the length of the amputation stump. In younger patients with tumors or trauma or other reasons for amputation, the classical ideal sites of amputation below and above the knee are selected. Below the knee, this is from 5 to 7 inches below the joint line. Above the knee, it is the junction of the middle and lower thirds of the thigh. Amputations above the knee should not be performed within 4 inches of the joint. There is no advantage in this additional length, and, more important, it interferes with fitting the patient with a prosthesis which is symmetrical with the other side. The knee invariably protrudes in cases of amputations which are less than 4 inches from the knee joint. The important level is below the knee in the patient who has an amputation for a vascular problem. It is advisable to preserve the knee at all costs, since use of the knee makes a tremendous difference to the patient in his ability to walk. The knee should be preserved even if it requires a 2-inch stump below the knee to reach viable tissue. Even though a below-knee amputation obviously will succeed because there is skin bleeding, the amputation stump should be

the shortest one which will give the greatest degree of function. In most instances, in elderly patients with vascular disease, transection of the bone about 4 inches below the joint line will leave an adequate amputation stump for functional purposes. The additional leverage of a long stump is risky and unnecessary. The amputation stump actually is not used as a lever to any great extent. The extension of the knee in the walking process takes place in the swing phase of gait, which is controlled almost exclusively by gravity and momentum.

SURGICAL PRECAUTIONS AND PITFALLS

When performing these short below-the-knee amputations, a long posterior flap should be preserved, leaving the scar anterior. There is a consensus among surgeons who do a great many amputations that the circulation in the posterior flap in vascular cases is far superior to that of the anterior flap. This is borne out by the observation that when necrosis takes place, it is almost invariably in the anterior flap. Experience with making longer posterior flaps has resulted in fewer cases of marginal necrosis or extensive necrosis in the anterior flap, which has been so commonly seen in the past. In addition, the amputation stump which has the long posterior flap is more suitable for the modern type of total contact plastic socket.

It must be emphasized that in all amputations, whether above the knee or below, the quality of the surgery in shaping the amputation stump is of paramount importance. Amputation stumps which are broad from side to side, those that have squared corners (often referred to as "dog ears") or are closed with irregular, depressed scars, can hardly survive in the immediate postsurgical fitting context. Certainly the patient cannot use a prosthesis early, since he cannot be fitted with a prosthesis until the stump is properly shaped. Tense skin flaps will not survive with or without this procedure.

It is necessary to emphasize that the skin closure is one of the most important factors in the entire procedure. There is no risk in placing tension on muscles if strangulating sutures are not used. In addition, there is no risk in suturing the subcutaneous layer with some degree of tension, which has a tendency to protect the skin sutures from tension. The objective in this case is to achieve primary healing. This requires bringing the skin together edge-to-edge, rather than surface-to-surface, and it is therefore unnecessary to use mattress sutures, piling up the skin margin. This function can be served by a subcutaneous line of sutures. All the skin needs is single sutures rather close together, bringing the skin edges precisely together, leaving no gaps and without any rotation. If there is a tendency for bulging of a corner, the skin must be trimmed so that the entire suture line is smooth.

In anchoring the muscles to the bone, in some areas there is great bulk of muscle which one must contend with. This bulk cannot be left in if it alters the shape of the amputation stump. Longitudinal wedges of muscle should be removed to create either a cylindrical stump which does not bulge or expand at the end, or a gently tapered stump, which is to be preferred.

In performing immediate postsurgical fitting, the surgeon is assisted by an experienced prosthetist in the operating room. It is the prosthetist who applies the stump sock over the contoured surgical dressing and proceeds to apply the rigid dressing. However, if early ambulation is considered, the surgeon may apply the rigid dressing, since walking will not be carried out in that socket. In many instances, the surgeon may prefer to apply the first part of the rigid dressing, consisting of the elastic plaster of Paris application, reinforced by regular plaster. The coupling device and walking pylon can be applied the following day or several days later by the prosthetist, making it unnecessary for the prosthetist to work in the operating room. Many modifications of this procedure can be carried out and yet preserve the principle and make it possible for the patient to be ambulatory at a very early stage. With good surgery, many patients can be fitted when the sutures are removed without the use of rigid dressing, if this is the choice by the surgeon, since a good amputation with a good postoperative, gently compressive dressing will result in a satisfactory amputation stump which can begin to bear partial weight in a walking device.

Many procedures have been developed by prosthetists for the application of the rigid dressing. There is a common misunderstanding, however, with regard to the functions and the construction of the plaster of Paris socket, as compared with that generally used in the definitive socket. No attempt is made to duplicate the definitive socket, since when the patient bears weight it is deliberately intended to transfer this weight to the soft tissues rather than to the bony skeleton. The definitive prosthesis transfers the weight to the bony skeleton, relieving the soft tissues. Transfer of weight to the bony skeleton is only performed in a minimal degree in the plaster of Paris socket, just enough to provide propioception through the bone so that sufficient feedback from the ground is obtained without having to compress the tissues to achieve it. The tension of the muscles, however, even if skeletal weight-bearing is not achieved, is sufficient to provide this proprioceptive factor. A similar situation occurs below the knee, where the total contact socket should bring a ground reaction to the extent that the patient feels that the whole stump is carrying the weight, with some increased concentration over the patellar tendon, which is a convenient and tolerant area. For this reason, in the project at New York University Medical Center, the casting devices were discarded early in the program, recognizing that the whole purpose of having the patient walk early is to rapidly create a situation in which the soft tissues adapt to the weight-bearing process and become accustomed to the tensions and are more rapidly conditioned. In above-knee amputations, a similar coupling device is applied to the plaster of Paris socket and an artificial knee which is adjustable in all directions is used. When the patient walks, however, the knee is locked so that there is a direct transfer of weight through the socket.

The impression of most investigators is that shrinkage does not occur as suddenly and rapidly and over as long a period with myoplastic amputation and early ambulation as when this procedure is not followed

by the use of the muscles in a standard amputation. Most certainly, where the muscles are retracting, not having been anchored down to the bone, the shape of the amputation stump changes and the comfort and function of any type of prosthesis is severely compromised. Shrinkage does not occur until actual walking takes place, so that one is deluded by the thought that, if an amputee waits long enough, the stump will adapt itself to an artificial limb. Even after waiting months, when a prosthesis is provided, shrinking then becomes rapid and maintenance of the fit of the prosthesis becomes difficult.

REHABILITATION TRAINING

Training of the amputee is quite a different process than it used to be. It was common to have amputees use elastic bandages for shaping and conditioning the amputation stump and, at the same time, do various exercises to preserve the range of motion, to prevent contractures, and also to relieve pain, which sometimes has been severe in the early postoperative period. This preprosthetic activity has been entirely bypassed with the use of the rigid dressing, whether or not early ambulation is instituted. There is much less postoperative edema to overcome with the use of the rigid dressing and pain has not been a prominent factor. The phantom, although present in some cases, has not been troublesome unless some breakdown in the technique occurred, wherein the cast itself was a source of irritation.

It must be recognized that amputation in the lower extremity, in 80 per cent of cases, is carried out on people over the age of 50 and with vascular impairment. More than half of the patients who have amputations in the lower extremity, in this older age group, are diabetic. It is important to recognize that, from a statistical standpoint, diabetic patients have bilateral disease and, either by trauma or deterioration, one lower extremity becomes nonviable and must be amputated while the disease is also present in the remaining leg. It is urgent in these cases to get the patient up early, in order to preserve the opposite limb.

Not many years ago, it was felt that if there was vascular disease in the remaining limb, the patient should not be fitted with a prosthesis. This resulted in statistics that indicated that if a diabetic patient lost one leg, he had a 50 per cent chance of losing the second leg within 2 years. These statistics basically will be altered after further studies, because diabetics no longer need to wait weeks and months for an artificial limb, while the remaining leg deteriorates through lack of use to the point where they *may not* use an artificial limb. It has been encouraging to see that minor evidences of necrosis, in terms of color changes and even superficial ulcerations, have healed satisfactorily with active use. This should not be overdone, however, by placing full weight on the remaining leg too early. Crutches should be used to protect both sides until the sixth week.

The use of a prosthesis alleviates excessive stresses on the remaining leg, if the patient has the capability of walking. Walking is far better than abstract exercise, since there is no exercise that the patient can do lying

in bed which is comparable to what happens when the patient stands on the leg, even if he does not walk on it. The kind of shoes the patient wears is extremely important, because the shoes as well as the walking and other therapy must not be traumatic to the remaining leg. Even if the patient is not able to wear a shoe, a large foam rubber boot can be used to allow the patient to put weight on the limb. The purpose of doing this is not so much to affect walking, but to preserve the remaining limb. The ground reaction and proprioception of weight-bearing has a satisfactory effect on circulation. The metabolic demand is not tremendously increased by weight-bearing alone, and partial weight-bearing in parallel bars or with the use of crutches appears to provide the greatest amount of circulation which the patient can derive from his circulatory tree.

Training procedures must be very meticulous. They are somewhat different from what they would be for a patient who has waited out his period of conditioning and shrinking. In the early phases, one is not concerned with the characteristics of gait or the percentage of weight-bearing. In principle, we prefer that a patient not be permitted to put full weight on an amputation stump in the first several weeks, even if he is capable of doing it comfortably and without pain. Obviously, the tissues require 6 weeks for final healing and there is no advantage derived from placing excessive weight on these tissues when they are not healed. Excessive tension in the muscles, particularly those which are attached for isometric contraction by myoplasty, is such that bleeding could occur or at least local irritation may ensue, resulting in some swelling in the amputation stump, interfering with the fit and comfort and circulation in the limb.

The use of the temporary prosthesis requires a very definite pattern. Weight-bearing begins with shifting of weight from one leg to the other. The patient is then given heel-toe exercises, so that he may feel where the leg is and learn to place his center of gravity over each leg alternately. He is then allowed to walk, but must carefully preserve the cadence of gait, and this should be watched carefully, since patients with pain break the normal cadence immediately. In these instances, much less weight should be placed on the prosthesis, but the walking process should not be terminated. By the time the patient has about 2 weeks of experience with the prosthesis, he has developed some degree of confidence and can follow instructions quite well.

In the first month, the greatest portion of the early shrinkage has taken place and the muscles are stronger, the amputation stump is firm, and sufficient time may have elapsed to determine whether the patient has the tolerance and capability for the use of the definitive prosthesis. This puts the doctor in a position to write a proper prescription for the final leg. When patients show variations from normally expected performance, these should be taken into account and incorporated into the prescription, so that feeble or poorly coordinated persons are provided with legs which are light enough for them to function with, within their capacity. Excessively heavy prostheses are discouraging to feeble elderly patients. It is recognized that any patient who really can walk, can do so

even with a heavy prosthesis. The early experience of most elderly amputees is that the prosthesis is too heavy, even though its weight may be within the accepted range of weight.

Prostheses can be made exceptionally light and, in many instances, they should be so made deliberately in order to make it possible for a patient to function, even at a low level, with a degree of comfort which is acceptable to him – which makes his ambulation much more practical than if he felt he was struggling in order to achieve real function. The plastic laminated molded socket is commonly used, but plastic is heavy. If a particularly light limb is necessary, it should be made of light woods and can even be made of balsa wood, which is treated to the extent that it will not deteriorate. Instead of using steel components in the knee and hip, there are plastic and aluminum components for these areas. Hand-made hip components, flexible hip joints and lightweight suspensions can be added to light legs for patients whose performance is low, in order to provide the greatest degree of comfort and stability, since in such cases the characteristics of gait are of only secondary importance.

CONCLUSION

A brief background of efforts on behalf of amputees and recent advances have been discussed. There are great advantages in ambulating amputees early. This can now be accomplished, but only with excellent surgery and supervision utilizing a new method of postoperative management and training. Amputation is no longer considered a mutilating procedure – it is reconstructive surgery by making the amputation stump a functional organ.

Taking a hard look at this new approach, one must be aware that these new techniques are more educational than procedural. Surgeons are advised not to undertake immediate postsurgical fitting if they are not familiar with the technique and principles involved. Help from a prosthetist cannot prevent a disaster. These techniques are now being taught in the postgraduate prosthetics education courses and they are accessible to those interested. The result of the experience at New York University is that, at the University Hospital, every amputee who has a reasonable potential for walking leaves the hospital ambulatory with a prosthesis about a month after amputation.

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Rehabilitation Following Traumatic Brain Damage

Immediate and Long-Term Follow-Up Results in 127 Cases

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Among patients with severe disability, one of the most neglected from a rehabilitation standpoint has been the patient with severe traumatic brain injury. These patients have in general been regarded negatively and have thus received little consideration or opportunity for restorative comprehensive rehabilitation programs. The reasons for this pessimistic attitude probably stem from the profoundly critical nature of the initial neurologic picture, the multiplicity of concomitant complications, the long time span of the recovery pattern, and the paucity of well-documented long-term clinical follow-up reports which might generate optimism.

In the decade from 1954 to 1964, 127 patients with sequelae of severe head trauma were admitted to the Institute of Rehabilitation Medicine, New York University Medical Center, to be evaluated for possible rehabilitation. A report[1] of the findings and immediate results with this group of cases was presented in 1964 at the Congress of Neurological Surgeons and will not be repeated here. A follow-up study of this group of patients, now 5 to 15 years later, constitutes this current report

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Table 1. *Nature of Patient Population*

Total patients	127
Total retained for treatment	102
Average length of coma	3 weeks
Average length of semicoma	5 weeks
Time lapse prior to rehabilitation	
(75% 1½ years or more)	7 to 34 months
Age range (80% 20 to 40 years of age)	13 to 79 years

to document the sustained results which one may expect from applying modern rehabilitation techniques to the severely brain-injured patient.

Of the 127 patients, 25 (20%) were found after initial in-patient evaluation to be too decerebrate to participate in an active rehabilitation program; 102 were retained for treatment. The 25 rejected were returned to their homes or to chronic care facilities, but were dismissed with definitive home programs designed to maintain joint mobility, to prevent contractures and decubiti, and to assume optimum urologic care. Where feasible, active exercises were also prescribed, all with the hope that with time further spontaneous recovery might justify reconsideration for a more comprehensive program.

Characteristics of the group are indicated in Table 1. Semiconsciousness, semicoma, or coma which was usual following the trauma averaged approximately 8 weeks. The time lag prior to admission to the Rehabilitation Institute ranged from 7 to 34 months, averaging approximately 20. Seventy-five per cent of the patients were male. Ages ranged from 13 to 79 years, but 80 per cent were in the 20 to 40 year age bracket.

The severity of the head injuries was reflected by the severity of concomitant injuries (Table 2). Among the 127 patients, there were 237 fractures exclusive of skull fractures; 10 amputations, usually of digits rather than entire extremities; 67 tracheostomies; 30 pneumothoraces; and 8 ruptured bladders. Other major complications included 40 severe decubiti, 30 frozen shoulders, and 200 other major joint deformities.

Significantly, the automobile was the weapon responsible for the injury in 85 per cent of the cases; varied industrial accidents, assault and attempted suicide accounted for the other 15 per cent.

The 102 patients were classified in four major groups (Table 3) as established by plain and contrast media x-rays, surgical findings, brain

Table 2. *Associated Complications (Other than Skull Fractures)*

COMPLICATIONS	NO. OF CASES
Fractures	237 (bones)
Amputations	10
Tracheostomies	67
Pneumothoraces	30
Ruptured bladders	8
Specific problems of treatment:	
Severe decubiti	40
Frozen shoulders	30
Other major joint deformities	200 (joints)

scan, and clinical observation. Twenty-five per cent had subdural hematomas, 20 per cent unilateral and 5 per cent bilateral. Group II, 19 per cent, were patients suffering from intracerebral hematoma or cerebral laceration or both. Group III, 10 per cent, were those whose symptomatology was primarily of brain stem or cerebellar pathway dysfunction. Group IV, 46 per cent, showed signs of diffuse cerebral and stem dysfunction.

The comprehensive evaluation of the 127 patients for rehabilitation feasibility consisted of examinations by physiatrists; physical, occupational, and speech therapists; psychologists; instructors in activities of daily living; social workers; and vocational counselors. Consultations in neurology, neurosurgery, urology, plastic surgery, psychiatry, and other specialty services were obtained as indicated. From the pool of information collected in this multispecialized way, rehabilitation feasibility was determined. Similarly, for those accepted for treatment, restorative programs were structured on the basis of deficits so identified.

The average length of stay of the 102 patients placed in rehabilitation programs was 4½ months.

The present follow-up of these original 127 patients, ranging from 5 to 15 years, was implemented to determine the long-term results in maintenance of rehabilitation benefits. Not only was this information collected on the group of 102 treated but also on the group of 25 rejected to assess wisdom of this judgment in these latter cases.

Of the 25 patients evaluated and rejected as not feasible for rehabilitation treatment, follow-up was possible in 23 (Table 4) either by personal re-examination of the patient or by interview with the family or with the patient's physician. Two were lost to follow-up because of geographical barriers. Of the 23, 18 were still living; five were dead. Of the latter, two died as a result of coronary occlusions, not unusual for their age group, and three deaths were related directly to debilitation secondary to the illness. These were complications from infected decubiti, repetitive genitourinary infections with hydronephrosis and pyelonephritis, pneumonitis and aspiration pneumonia.

Of the 18 still living, 14 men and 4 women, none had shown any significant improvement in the interval since discharge from the intake evaluation process. On the other hand, significant numbers of complications had developed. Major decubiti had played a role in further debilitation in at least 105 instances. Genitourinary infections, despite prophylactic care, had been recurrent at an average of four per patient

Table 3

nature of lesion of brain (102 cases)	per cent
Group I: Subdural hematoma	25
Unilateral	20
Bilateral	5
Group II: Intracerebral hematoma or cerebral laceration or both	19
Group III: Posterior fossa lesions	10
Group IV: Diffuse contusion	46

Table 4. *Follow-Up of 23 of 25 Patients Rejected for Rehabilitation*

			INSTITUTION		HOME		
		Male	Female	Male	Female	Male	Female	CAUSE OF DETERIORATION
Total cases	23	18	5					Major decubiti: 6/pt.
								Genitourinary infection: 4/pt./yr.
Alive	18	14	4	9	4	5	0	Respiratory disease: 5/pt./yr.
								Contractures: worse
Dead	5	4	1	3	1	1	0	2 coronaries
								3 chronic infection

per year. Similarly, debilitating respiratory disease had occurred on the average of five times per year per patient. Previously existent contractures were worse, and four patients who had not had significant contractures were reported as now being "fixed in a sitting position."

Thirteen of the surviving 18 patients are now institutionalized. It is of interest that 5 of 14 male patients remain at home, whereas none of the surviving 4 women do. In areas where there are available supportive programs, such as visiting nurses, part-time housekeepers and aides, it would appear that the housewife with supplementary care is more likely to be able to manage the major responsibility for the care of her husband. Conversely, since supplementary programs are insufficient for provision of care in the home without a full-time partner in attendance, it is either cheaper or more convenient for the working husband to institutionalize his debilitated wife. The fact, also, that four out of the five deaths took place in institutions was interpreted as indicating that the more debilitated and complicated patient, regardless of sex, tended to be institutionalized.

Follow-up functional status of the treatment group of 102 patients was obtained in 93 of these. Two patients had died, and seven were lost to follow-up. Table 5 is a functional tabulation of the remaining 93. Unlimited ambulation which had been regained in 18 cases upon discharge from the hospital was still unlimited 5 to 15 years later. This had been an important factor in enabling these patients to live at home, to seek and maintain employment, and to form social contacts. Of the 23 patients who, upon discharge, had become adequate ambulators (i.e., able to leave their homes and travel independently via public transportation with or without canes, crutches, or other aids), 20 remained adequate ambulators. The three who regressed all indicated that the amount of energy required to ambulate and the fatigue produced therefrom were sufficient in degree to make reliance upon wheelchair or help more desirable. Thirty-five of the patients who had accomplished partial ambulation (i.e., capable of negotiating short distances but otherwise in need of manual or wheelchair assistance) showed greater regression in that only 20 maintained this level of activity. In these 20, this freedom

in ability to at least transfer from wheelchair to car, or wheelchair to bed or toilet, remained utmost in importance.

Independent toilet care was maintained by 58 of the 60 who had achieved this during rehabilitation. Freedom from dependence on others for help in these highly personal needs was again a very important factor in the continued acceptability of the patient in his home environment, as well as in vocational and social contacts.

In dressing and feeding activities of the 40 patients who had become independent, all had maintained this at the time of follow-up. Some used special clothing and self-help devices, but required no other assistance. Twenty-eight patients were graded as partially independent at time of discharge from the hospital, and 24 remained so at follow-up. Because of the laborious and time-consuming process involved in cutting food independently and in dressing, four of the patients had given up these activities almost entirely because of the time factor.

Considering function of what was previously a severely involved hand, 13 patients upon discharge from the hospital were graded normal or nearly normal in motor function, and in all 13 this function was maintained. Of 15 who had developed good supportive hands, 12 were continuing to use this involved hand to a significant extent. In three cases, bimanual activities had fallen to very low levels due to increased spasticity. Among 10 other patients whose hand function had been improved by use of orthotic devices, five continued to use these with benefit. The other five had discarded them as too cumbersome and adding little to the usefulness of the hand.

Fourteen patients with significant dysarthria who had improved in ability to communicate at the time of their discharge maintained this improvement. Another five who, upon discharge were nonfunctional speakers, were now reported by their families to be quite understandable. Two of these, however, were personally re-examined and were considered to have made no change. It seems likely that the close associates

Table 5. *Follow-Up on Treatment Results in 93 Cases*

	FUNCTION WHEN DISCHARGED	FUNCTION NOW (5-15 YEARS LATER)
Ambulation:		
Unlimited	18	18
Adequate	23	20
Partial	35	20
Independent toilet care	60	58
Dressing and feeding:		
Independent	40	40
Partial	28	24
Hand function (38 cases):		
Normal motor function	13	13
Adequate for support	15	12
Improved by orthoses	10	5
Speech:		
Dysarthria, improved	14	14
Aphasia, improved	10	10

Table 6. *Vocational Results*

CAREER CATEGORY BEFORE TRAUMA	RETURNING POST REHABILITATION	CONTINUING SUCCESSFULLY AT FOLLOW-UP:	
		ORIGINAL GOAL	OTHER JOBS
Students	13 of 19	7	2
Housewives	14 of 19	10	0
Executives	9	6	0
Skilled trades:			
Former employment	9 of 20	7	1
Retrained	10		7
Unskilled laborers	0 of 17	0	3
Independent at home	20	13	

of these patients had probably developed a keener interpretation of the symbolic sounds and gestures which the patients used to make wants known. Of 10 aphasic patients who had improved significantly at time of discharge, all maintained this improvement but showed no significant new gains in vocabulary or any new forms of symbolic communication. Of 16 aphasic patients unimproved in speech at time of discharge, no improvement was evident on follow-up.

Optimally, the goal for each patient should be his return to the activities in which he was engaged prior to trauma despite his residual disability (Table 6). Of the original group of 102 treated patients, 19 were students, 13 of whom upon discharge had plans to return to their studies. Ten were subsequently successful in completing a high school or college course in which previously enrolled, seven by attending public facilities and three with private tutoring at home. Three of this group achieved educational goals higher than pre-injury ones. The nine remaining were unsuccessful in returning to studies, but two of these as well as seven who completed studies are now working.

Fourteen of 19 housewives upon discharge from the initial program had become independent in their household tasks to an extent of 50 per cent or more. At follow-up, 10 had maintained this level of working ability. Two required a significant amount of help; two others had given up household activities completely and required full-time homemaker help. Depression was a significant factor with these latter four patients.

Of nine professional or executive men who returned to full or part-time work, six were still at work at follow-up. Of the three who had stopped working, one had reached retirement; the two others elected to do no work rather than carry only half their previous responsibility. Of 20 men previously engaged in skilled trades, nine had returned to their trades; seven were still at these. Seven others of this group had been successfully retrained and were working in new less complicated jobs. In contrast, however, of 17 unskilled laborers, none was able to return to work in that capacity, and only three had been retrained in other fields, mainly bench assembly jobs.

Forty-seven patients in the initial study had shown insufficient improvement during their rehabilitation to live totally independently.

Twenty of these, however, had gained sufficient independence in self-care to sustain themselves at home during the day. At follow-up, 13 of these remained independent at home during the day requiring no help from family or visiting nurse; the seven others required part or full-time help because of increasing spasticity or respiratory, skin, genitourinary, or emotional problems.

Twenty patients originally discharged home under the care of their family with visiting nurse aid had become institutionalized at follow-up. Again, it is of interest that among these, the percentage of women was greater than that of men. The families who had to resort to institutionalization gave as reasons fatigue on the part of the family member most responsible for patient's care, depression of the patient or of the family, or the financial need of the spouse to seek work in order to support minor children.

DISCUSSION

While almost half (46 per cent) of the head-injured patients reported here were returned to some form of gainful employment, this statistic is not significantly higher than the average in other severe disabilities of other etiologies. While some patients did become employed in family businesses or were assigned to light jobs by their trade unions, the percentage of these seems similarly not at variance. The significant fact, however, is that this category of severe disability can more often than not be appreciably benefited by an intensive rehabilitation program.

A major positive factor made apparent at follow-up was the value of continuing care after discharge. Those patients who lived near a rehabilitation center or who maintained contact with an interested physician, physical therapist, or, quite importantly, a social worker, were more likely to sustain their rehabilitation gains. Similar continued interest from medical or paramedical personnel also played a significant role in assuring success in social and work adjustments.

Among those patients who showed major loss of function not attributable to systemic complications, the factor of isolation from qualified advisers and therapists was strongly evident in their histories. Such patients, left to their own resources, tended to lose function they had gained, and a higher percentage of this group became in need of institutional care or full-time help at home. This follow-up finding points up the critical need for continuing aftercare, both medical and social.

SUMMARY

One hundred twenty-seven patients disabled from severe head trauma were seen for rehabilitation evaluation at the Institute of Rehabilitation Medicine in the decade 1954 to 1964. Approximately 80 per cent were accepted as feasible candidates for a comprehensive rehabilitation treatment program.

Of these patients, 118 have now been followed for 5 to 15 years and their post-treatment courses are reported here.

Significant improvement is possible in a substantial percentage of the severely brain-injured through comprehensive rehabilitation care.

Maintenance of these treatment gains is in large measure dependent upon close follow-up contact with responsible and effective medical and paramedical rehabilitation personnel.

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Driver Education for the Physically Disabled

Evaluation, Selection, and Training Methods

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From its inception, one of rehabilitation's goals has been to apply new science and technology that might improve the way the disabled live and work. As our society became increasingly complex, driving a motorized vehicle assumed the significance of a privilege, if not a right, for all citizens. For the physically disabled it is often an acute necessity for mobility in vocational as well as avocational pursuits. Teaching the competent disabled to drive then became a natural function of rehabilitation services in large urban centers.

One such program was undertaken by the Institute of Rehabilitation Medicine. Almost from the beginning of this program, 10 years ago, the Institute of Rehabilitation Medicine, New York University Medical Center and The Center for Safety, New York University, have pooled their resources to bring to the disabled as sound a program as medicine, psychology, biomechanics, and resources would allow.

Surveys conducted by Herner and Ysander, as shown in Herner's report,[2] reveal that the disabled and the elderly do not appear to constitute a greater danger in traffic than other segments of the population. Several studies have shown that drivers with relatively severe physical limitations may have safe records, if they are carefully supervised by their physicians. In Massachusetts, for example, a satisfactory safety record has been found for certain high-risk drivers permitted to hold licenses and drive under a program of continuing medical surveillance.[1]

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Driver education is seen as a continuum in the total activities of daily living process for the patient. Just as he must practice and learn or relearn techniques that are safe and efficient for dressing, walking, self-care, and so on, so must he learn and practice techniques relating to the proper use of the motorized vehicle. The ultimate goal is closely bound to his rehabilitation effort for increased mobility, new independence, and, where possible, a return to job and community. Patient motivation has been found to be high.

The program of the Institute of Rehabilitation Medicine and Center for Safety, New York University, consists of evaluation and training phases. Evaluation and training are further broken down for the new learner and for the relearner.

The diagnostic categories selected for our program from among our patient population have been:

> Traumatic spinal cord injuries
> Nontraumatic neuromuscular disorders
> Birth defects
> Amputations
> Cerebral vascular accidents

Since the inception of the program, approximately 300 patients have been involved. The last failure in a New York State road test was in 1964; the effectiveness of the program is thus apparent.

PHASE ONE: EVALUATION

Phase one is the period in which all services (medicine, physical therapy, occupational therapy, psychology) available to the patient pool as much information as is at that time available for the driver educator. This information is made available mainly to assist him in establishing optimum procedures for the individual patient.

The members of the staff representing the Center for Safety then administer various psychophysical tests to ascertain possible problems in such functions as visual acuity, color recognition, depth perception, and field of vision.

During phase one, arrangements for continued practice in self-transfer into the car may be recommended, and assistive devices such as lifts or hoists and special driving aids such as mitts, gloves, and adaptive devices may be considered. In addition, new designs of controls or individualized adaptations to facilitate the driving task are studied.

The sum of the above plus capability to transfer into and out of the car, balance while in the car, range of joint motion, muscle power of remaining extremities, prosthesis or orthosis, as recommended, are assayed collectively for correlation with a view toward provision of proper assistive aids to make driver training possible. This information plus that obtained from actual behind-the-wheel driving then provide the driver educator with a basis for deciding if the subject is suited for continued programming.

A model car with all necessary adaptations is available at the Institute of Rehabilitation Medicine. Here, some of the transfer needs are

practiced and mastered, balance and position behind-the-wheel are evaluated, and time and nature of reaction are studied.

Although the simulator offers some excellent features (such as ability to observe responses to emergency situations), the lack of kinesthetic sensation, insufficient feedback, limited peripheral input, and lack of scanning ability, all so important for the disabled, detract from its use as the single tool to give conclusive information during evaluation. Hence, as soon as it is feasible, arrangements are made to get the patient into the training car with the driver educator to obtain more precise evaluative data.

The evaluative process may take from two to eight sessions of behind-the-wheel activity. The resulting information is shared with
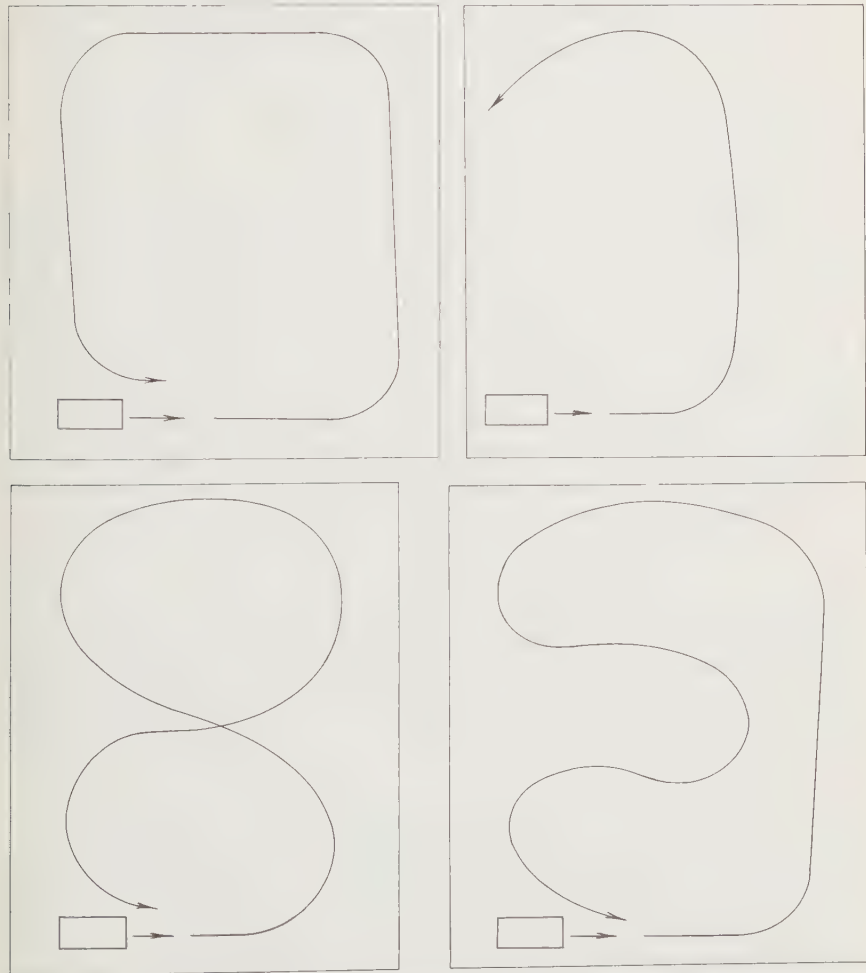
Figure 1. *Top*, Good planning and poor planning in executing a counterclockwise maneuver. *Bottom*, Correct and incorrect judgment in executing a figure-of-eight maneuver.

the referring physician, who then must recommend action regarding continuation and nature of training.

Although every diagnostic category presents a unique problem for the driver educator and the consultants, it has been found that the traumatic quadriplegic, making up the largest participating group in the program, will require the most sophisticated assistive devices, while the hemiplegic patient may need only a minimum of assistive devices but will require extensive testing for possible perceptual difficulties (see p. 692).

The behind-the-wheel practice during phase one is conducted in a private parking area where a patient can drive without a permit or a license; at this time, various controls and devices that the patient may be using are demonstrated and tried.

Test maneuvers which have been found useful include a series of circles in the clockwise direction. When these have been carried out correctly, the figure-of-eight maneuver follows. Because of the complexities involved in this maneuver it is used to check coordination, perception and the planning capabilities of the patient. When changes in direction are requested from left to right and right to left, these then become critical areas of evaluation (Fig. 1).

Experience from the Institute of Rehabilitation Medicine program indicates that patients without brain impairment execute the requested maneuvers with little or no difficulty, usually within two sessions. However, many patients with moderate brain impairment and left hemiplegia experience subtle to obvious perceptual difficulty. This does not usually hold true for right hemiplegia. Such difficulties become manifest in an inability to scan the environment and to plan in an acceptable manner. Inadequate performance is demonstrated by the car continuously "running out of space" when attempting to drive in the circular pattern and by difficulty in maneuvering at the start, in maintenance of a given speed, and in completion of requirements in a few sessions.

PHASE TWO: DRIVER TRAINING

The purpose of phase two, driver education or training, when recommended by the referring physician, is to take into account the patient's deficits in ability to drive safely and to provide the necessary corrective behind-the-wheel practice under varying conditions. Approximately 20 to 25 lessons, or more if needed, are given for training in light to heavy traffic.

Defensive driving techniques are continuously stressed with the disabled in traffic during the training phase. Desirable attitudes are introduced early in teaching the new driver, and an attempt is made to correct any poor driving patterns or habits with those who have had previous driving experience. In general, highly encouraging results have been evidenced in the training program. However, for more objective evaluation of its effectiveness it will be necessary to follow the patients processed at the Institute of Rehabilitation Medicine to establish their driving record and problems over a period of 3 to 5 years fol-

lowing their discharge. Such a follow-up research design is currently being developed jointly by the Institute of Rehabilitation Medicine and the Center for Safety.

Driving Aids: Design and Development

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For the hemiplegic patient with only one functional arm, the paraplegic with paralyzed legs, the quadriplegic with lost hand function and weak or no wrist function, and for the many others handicapped by diverse physical deficits, the design and development of driving aids to safely and effectively compensate for the impaired functions is a critical goal of the driver education and research program.

While the actual design of these devices is a function of an orthotics-prosthetics research program, the identification of mechanical needs and the conception and development of driving aids for the handicapped involve a team effort. Specifically, a physiatrist, the driver educator, the physical therapist, the orthotist-prosthetist, the bioengineer, and occasionally the occupational therapist are the nucleus of this team. Each contributes in his own way to the evolution of the assistive device needed by a specific patient.

Although most new devices are initially designed for a particular patient, it has been found that these often prove useful to many other patients. Figures 2 through 6 illustrate a number of the devices developed in this research program. The first two are now in routine use by quadriplegic patients.

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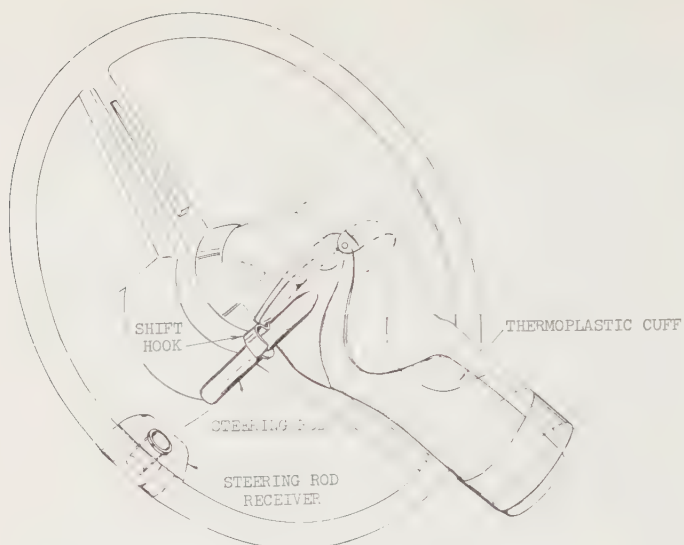
Figure 2. Driving cuff substitutes for grasp in steering and shifting, and stabilizes the wrist.
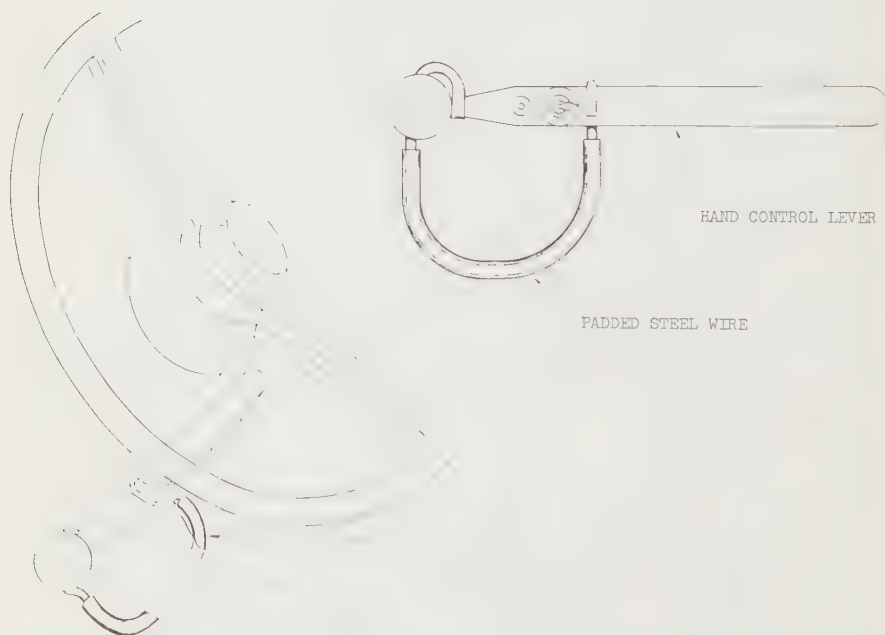
Figure 3. Wire wrist support stabilizes the wrist for push-pull brake and accelerator control.
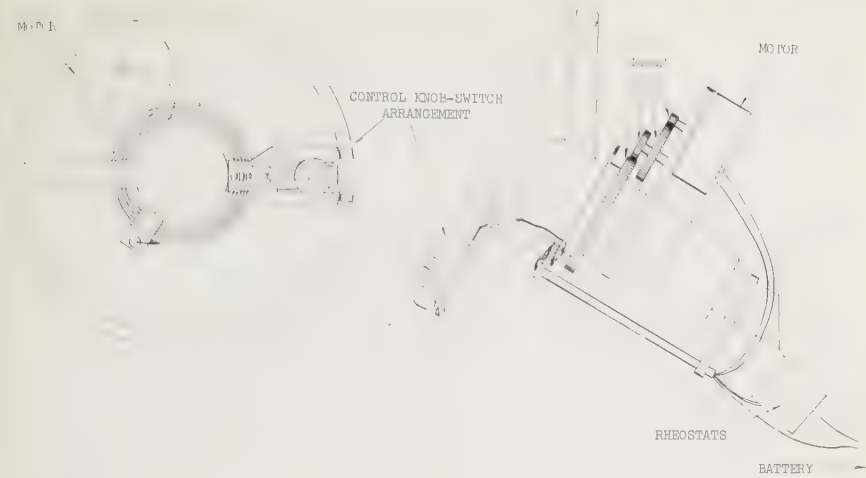
Figure 4. Steering device to reduce force and excursion also provides adjustable steering speed.
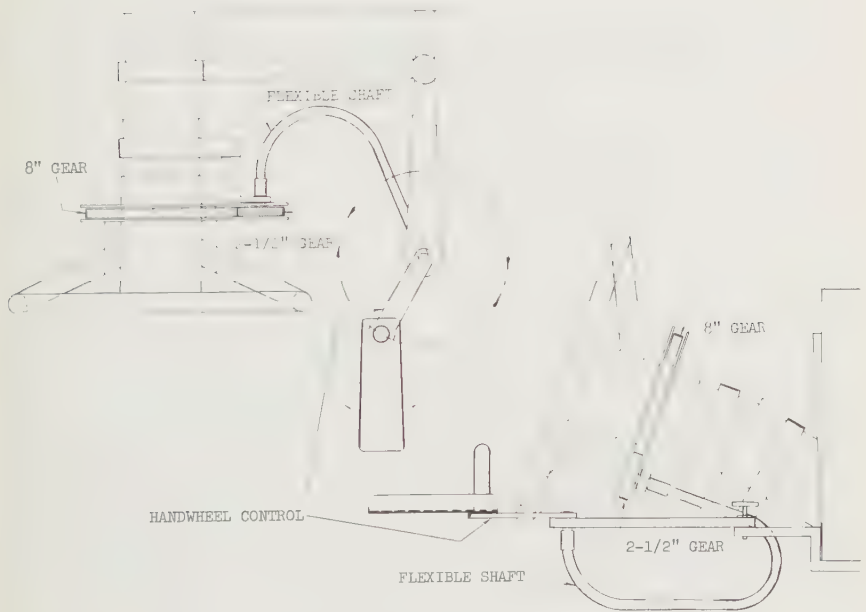
Figure 5. Remote-control steering is made possible by locating a handwheel in the most useful position. This device also acts to reduce the force required to operate the steering mechanism.
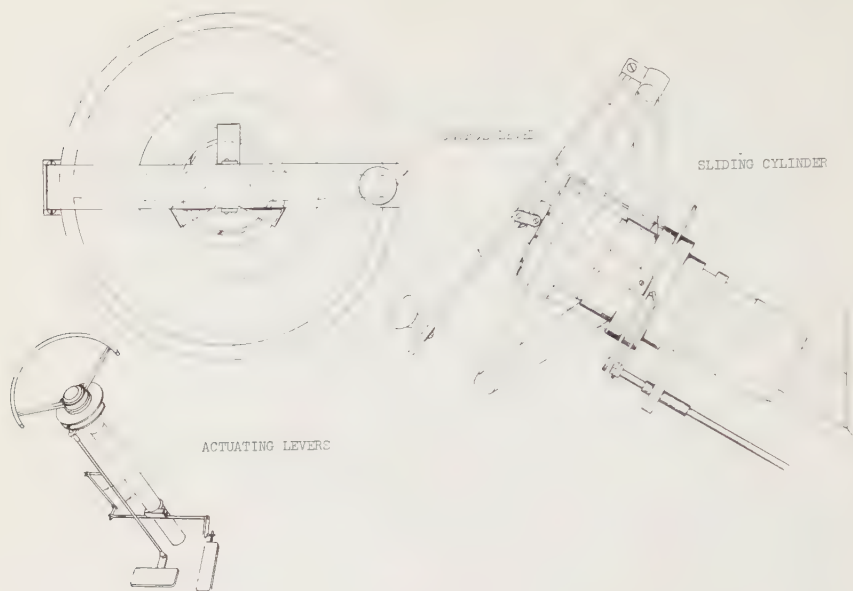
Figure 6.   Steering, braking, and accelerating can be controlled with one hand through the use of this device.

Psychological Factors Affecting Driving Behavior in the Disabled

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Studies on the effect of emotional states on driving behavior[8, 12, 15, 16, 20, 22, 25, 27, 28] have shown that the chronic violator and the accident repeater tend to resent authority and to object to restrictions placed on their actions. Many have erratic job histories. These people are often quickly aroused to anger; some may be irrationally competitive. Excessive impulsiveness that precludes planning ahead or results in lack of adequate judgment is a poor prognostic sign for safe driving.

In studying males with spinal cord injury, Fordyce[14] found a group who showed "impulse-dominated" behavior. In driver training of the disabled, it is important to determine whether the patient tends to be an

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imprudent person. Excessive emotionality that results in rapid fluctuations of mood and feeling may also impair performance. Excessive anxiety that results in preoccupation or in inability to make quick decisions with good judgment, in daydreaming, inability to sustain attention on the driving task, or profound depression that results in psychomotor retardation or suicidal impulses, are also poor prognostic signs.

The psychological meanings, both conscious and unconscious, of driving are important factors to consider. For example, a person may drive a car to feel a sense of power. That meaning is not uncommon in America generally. In the disabled population, it may serve as a compensation for the experience of loss of power resulting from the disability. This factor makes training the disabled to drive one of the important contributors to improvement in morale. If, however, this compensatory mechanism is excessive, it can become dangerous. In general, studies concerning safe driving have shown that above a certain minimum, driving skills are less important than are attitudes.[20]

Body Image

Body image is another psychological factor important in driving. This term is used to indicate the notions a person has concerning himself and his body.[4] Abt[1] writes that the term refers to the picture a person has of himself as a person "extended into space, a person . . . who comes into contact with other spatially-extended bodies. . . ." When any person starts to drive a car that is new to him, he usually has a feeling of unfamiliarity. He probably says something like, "I don't know where my fenders are yet." When he does know, the car, as a unit extended in space, has become incorporated in his body schema. In order for a person to be a good driver, the car that he is driving must become a part of his body image.

One of the major adjustments traumatically disabled people have to make is in modification of their body image. Congenitally disabled persons frequently have problems not so much in modification but in development of clear and stable body images. Damage to the brain also can affect body image. Those with body image problems, especially brain-damaged patients, may have difficulty following instructions related to their bodies, or have difficulties with right-left orientation. They sometimes cannot localize body parts correctly.[3] Some hemiplegics, for example, tend not to look or to look only cursorily to the side of their disabled bodies. If a left hemiplegic, for example, only superficially scans his environment on the left, he will quickly find himself in trouble when driving a car. When a patient is showing difficulty in learning to drive, the possibility of body image problems should be considered. For the traumatic disabilities especially, there may well be an optimum time to start driver training. Perhaps such training should be delayed until the patient has begun to adjust to the new body schema necessitated by his disability.

Intellect

Above a certain minimum, over-all intelligence is not a significant factor in safe driving.[8, 12, 17, 19, 25, 27, 28] A modicum of abstract reasoning is

necessary, however. Ability to plan ahead is important. Good judgment, of course, is crucial, but judgment is not a purely intellectual matter. Indeed, the factors already discussed, as well as those yet to be discussed, influence judgment.

Perceptions

Visuomotor factors take on particular importance in teaching the disabled to drive. Even in the able-bodied, it is stated that eye-hand and eye-foot coordination are more significant than visual acuity.[9, 21] Night vision and glare resistance lessen with age, particularly after age 45. The population pyramid is becoming taller,[2] and rehabilitation centers can expect to deal with more and more older people. Such centers should therefore be especially cognizant of the effects of aging on vision in driver training of the older patient. Most people are unaware of these changes, and older patients should be specifically cautioned to drive more slowly at night. General fatigue and visual fatigue[9] can result in impairment in perception of spatial relationships and narrowing of the visual fields.

The energy level of the disabled patient, particularly the older one, should be considered in a program of driver evaluation and training. Hemiplegics, for example, often tire easily.

Blinking is a related symptom that should be considered. In experimental work, Pulton and Gregory[24] indicated that blinking impairs performance on some tasks. Brody[9] reports that blinking is often associated with inattention, which has been postulated as an important cause of accidents. Barmack and Payne,[5] for instance, reported a high incidence of "perceptual surprises" in a group of airmen who had had private motor vehicle accidents. A recent paper by Diller and Weinberg[10] points up the attention problems of some hemiplegics. Some brain-damaged persons have difficulty in shifting their attention from one thing to another.[3] Such persons may repeat an activity over and over unless something outside themselves interrupts it. If perseveration is severe, the patient will not be able to change his behavior synchronously with the ever-changing conditions that are inherent in the driving task.

Some brain-damaged patients have difficulty distinguishing foreground from background.[3] Moreover, they cannot always select the most relevant visual cues to which to respond. Birch and Belmont[7] have shown that some brain-damaged patients have difficulty in coordinating information received from the various sense modalities. Effects of foreground-background problems within and between sense modalities is not known, but it would not be surprising if reaction time were affected. It is likely that difficulties in distinguishing foreground from background would make driving hazardous. Indeed, Tassman[26] emphasizes the importance of contrast over that of visual acuity in the visual aspects of the driving task.

Some brain-damaged persons, certain cerebral-palsied individuals for example, have fluctuating eye dominance. If a normal person stares with only his right eye at his upraised finger and then, without moving either his finger or his head, he stares at that upraised finger with his

left eye, he will see his finger jump. In somewhat analogous fashion, if an individual has fluctuating eye dominance, it is likely that objects that he sees are not perceived as stable. If this instability is compounded with a constantly shifting visual environment, as is the case in a moving automobile, it is not hard to imagine the kinds of difficulties that can occur.

Peripheral vision is of great value in calling attention to outlying objects.[11] Berens[6] reports that a visual field of less than 140 degrees may be unsafe for driving. There are a number of medical conditions that result in restriction of the visual field, the one most frequently seen at a rehabilitation center being hemiplegia. It is often difficult to train a person with hemianopsia to move his head to compensate, but active training in this regard is necessary in teaching driving to a patient with this kind of problem. In evaluating driving performance, the important aspect to consider is not so much the visual field, but how the patient uses his visual field in relation to driving. Some brain-damaged persons, certain of the cerebral-palsied and left hemiplegics for example, may rotate their copies of geometric designs by 90 degrees. Some have problems lining up objects visually. For example, in following a line of words, their eyes may skip to another line. Such patients may have difficulty in parking a car or passing another car.

Despite the many visual and visuomotor difficulties a disabled population may be heir to, studies of nondisabled drivers have shown that "except at the very lowest extremes, psychophysical deficiencies are not associated with accidents and violations in a significant degree."[20] These over-all findings suggest that presence or absence of defects is not sufficient to eliminate a person from driver training. Rather, an evaluation must be made of the performance of the patient in relation to driving.

Summary

Briefly discussed are some of the effects of emotions, body image, intellect, and perception in the driving performance of the disabled. The task in rehabilitation is to know the problems well enough to be able to teach the patient ways of recognizing and circumventing his disability in order for him to live a more mobile, independent, and satisfying life.

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Telephone Services for the Disabled

Patient and Equipment Evaluation

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A recently completed 2-year study, carried out at the Institute of Rehabilitation Medicine of the New York University Medical Center, resulted in the development of an evaluation and training program designed to assist the disabled in acquiring and using the telephone equipment most suited to their needs. The study, sponsored by the American Telephone & Telegraph Co., resulted from preliminary discussions between that company and the Institute concerning the needs of the disabled with respect to telephone services and equipment.

PURPOSE

The purpose of the study was to determine the following: (1) which standard items of equipment could be used by disabled persons without requiring any modifications; (2) which standard items of equipment could be adopted for use with only simple modifications; (3) which disabilities would necessitate the development of new equipment in order to allow for independence in telephoning; and (4) would it be feasible to develop such new equipment on a standard basis or would the requirements of certain disabilities have to be met on an individual basis?

It was hoped that the specific requirements of certain disabilities could be matched with specific equipment. Thus certain types of dis-

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abilities could be categorized and the telephone needs of the patients outlined accordingly. This would allow more convenient accommodation of the disabled by the telephone companies.

The results of the study were to be disseminated in two publications. First, an information manual for the Bell Telephone System would be prepared. This would be designed to assist telephone company representatives in supplying the disabled customer with appropriate equipment. Second, a Rehabilitation Monograph would be published by the Institute of Rehabilitation Medicine. This would provide rehabilitation centers, and appropriate medical and paramedical personnel, with information to assist them in evaluating the needs of the disabled for telephone service, and to make them aware of the types of equipment and modifications that are available.

METHOD

Three hundred and five patients with upper extremity disabilities were studied. The evaluation and testing was carried out in the hospitals, the homes, and in the vocational settings of the patients. They were first tested with standard telephone equipment, following the normal pattern of use.

The residual functional capacity of each patient was analyzed and his performance with the various items of equipment was studied. Consideration was also given to his vocational and social requirements with respect to his need for independent use of the telephone.

In a number of instances disabled persons had already developed their own techniques for using telephone equipment. Their methods were studied and where feasible were used as an evaluation technique and instruction method for similarly disabled patients.

The various items of telephone equipment were evaluated with respect to their physical requirements for normal use. This data was correlated with the information obtained from the functional evaluation of the disabled patients. An attempt was then made to establish criteria whereby items of equipment could be matched to the individual disabilities.

CONCLUSIONS

From a technical standpoint it is possible to provide a suitable telephone installation for almost any disabled person. This often requires the combination of appropriate telephone equipment with the patient's own prosthetic or orthotic devices (prosthetic hands or hooks, tenodesis, splints, universal cuffs, etc.) as a necessary adjunct to successful telephone use.

The telephone needs of almost all disabled persons can be met by the available telephone equipment, either unmodified or with only a few modifications. This standard equipment can be used in four ways: (1) in the normal manner, without special devices, adaptations, modifications, or changes in positioning of the equipment; (2) in an unorthodox

way, such as by repositioning the equipment (e.g., turning the telephone set around to facilitate rotary dialing by a quadriplegic); (3) with minor equipment modifications (e.g., placing a lever over a pinch-operated turnbutton switch to allow operation of the switch by lever pressure rather than by the pinch mechanism, which is often lacking in patients with upper extremity disabilities); (4) for a purpose other than that for which it was originally intended (e.g., using a line button as an "off-on" switch). This allows one to make call connections and disconnections by merely pushing a button, thus permitting the patient to leave the relatively heavy receiver permanently off the cradle.

In determining the ability to use a telephone independently, the technique that the patient employed to operate the telephone was found to be as important as the type of equipment.

Important information about the telephone itself was obtained, such as the amount of pressure required to operate various levers and buttons and how the shape, size, and weight of various items influenced the ease with which they could be used. This information will prove helpful when future equipment is designed for use either by normal or by disabled persons.

Separate devices were often required to hold the telephone receiver of the ear. Evaluation of these holding arms revealed that two types were of particular value. Although available through commercial sources, such devices are not ordinarily furnished by the telephone companies.

Little correlation was found between the broad diagnostic categories into which the various types of disabilities could be classified and the types of equipment found most useful to the patients. The variations in physical function, residual capacity, basic agility and skill on the part of the patient, and social and vocational needs, even among patients with the same diagnosis, showed that each patient must be evaluated individually as to his requirements for telephone equipment.

As a result of the study a technique was devised to functionally evaluate the telephone needs of a disabled individual and prescribe the most suitable equipment for his use.

DISCUSSION

All disabled persons who have no speech deficit can achieve independence in the use of the telephone when provided with the equipment that best compensates for their physical limitations. Except for those who have a visual perceptual problem or uncontrollable involuntary movements, most patients have the capacity to use a rotary dial.

Successful use of a rotary dial requires suitable muscle strength in the arm (or neck and trunk), equipment which offers a minimum of resistance, the employment of an appropriate technique compatible with the severity of the patient's disability, and training in the development of the necessary skill. Those patients who are unable to use a rotary dial will be able to dial without assistance as push-button (Touch-Tone) service becomes more readily available. Where the disability is so severe

that no form of dial is usable, an arrangement may be made whereby the telephone operator can be reached through one simple motion. The calls can then be made verbally with the assistance of the operator.

One of the difficulties frequently encountered when a disabled person, or those concerned with his rehabilitation, contacted the telephone company for assistance was the lack of any guide or information to aid in solving his individual problems. Often the telephone company engineers had to be called in to devise a special installation for a single disabled person. This process was inefficient, expensive, and time-consuming. The publication of the manuals that resulted from the study will overcome this problem by giving the telephone company's representative guidelines to follow in adapting telephone equipment to a specific disability. They also point out the fact that there is much less need for special elaborate installations than had previously been assumed. A better understanding of the patient's disability by the telephone company's representative, and the application of simple appropriate modifications to already existing equipment, will suffice in most instances.

The study showed that there are many items of equipment already available to help solve some problems. Holding arms, for example, to hold the telephone receiver to a patient's ear have been commercially available for some time. Concerning specific telephone equipment, there are certain items now in use that can be replaced with other more suitable ones. The methods used to connect and disconnect calls have often been crude. Heavy metal bars or "kiddy-proof" guards were frequently used to keep line buttons down. This study showed that the line transfer switch on a two-line telephone or the line buttons on a six-button telephone can be used much more conveniently for this purpose.

The weight of the telephone equipment is often a factor in its use. The standard 11½-oz. receiver frequently proved to be too heavy for the patients. This can be replaced by a readily available receiver which weighs only 8½ oz. and which was found to be more suitable for many patients.

Some newer items of equipment such as the Card Dialer and the lightweight headset solved the problems of some patients who could not previously be helped.

In this study the full range of Bell System telephone equipment was evaluated. As a result, information is now available to assist the disabled person in choosing the equipment best suited to his needs. As previously noted, this information will be distributed in the form of a manual throughout the Bell System.[1] It is designed to assist the Bell representative in providing for the needs of the disabled customer. A monograph published by the Institute of Rehabilitation Medicine for use by rehabilitation personnel will outline an evaluation technique and provide a full equipment survey.[2]

The Bell System telephone equipment used in the study is similar in function to the telephone equipment employed by the independent telephone companies. Thus the findings of the study are broadly applicable throughout the United States and not just in the territories served

Figure 1. This patient sustained a traumatic spinal cord injury and has a neurological level at C6. Distal to the shoulders his voluntary muscle power is limited to elbow flexion and wrist extension. He uses a lightweight headset which he attaches to his glasses. (The headset normally has a head band which is more difficult for a handicapped person to manipulate.) This apparatus plugs into a jack in the rear of the telephone, and calls can be connected and disconnected by means of a button. This eliminates the necessity of removing the regular heavy handset from the telephone cradle. The problems of loss of upper extremity muscle power and hand function are both solved by this type of arrangement.

Figure 2. This patient is a rheumatoid arthritic with ankylosis of both elbows and wrists. She uses a goose-neck arm with desk attachment to position the "wear-it-or-hold-it set." (This set may also be held in place with a head band.) The set plugs into a jack at the rear of the telephone, as shown. On the upper right corner of the telephone is the turn button with lever modification, the switch which connects and disconnects calls. In this type of disability such a modification is more easily operated than the conventional rotary or pushbutton switch. The necessity of picking up and holding the handset is avoided. The problems of loss of range of motion and easy fatigability, inherent in rheumatoid arthritis, are both solved by this type of arrangement.

by the Bell System. There are well-established routines whereby copies of Bell System printed material – such as the information manual on service for the disabled – can be purchased by independent telephone companies.

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Home Planning for the Severely Disabled

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In planning a rehabilitation program for the severely disabled patient, one must be concerned with what will happen when he returns home. If the person is dependent on a wheelchair, there is a likelihood that he may not even be able to get into his house. Considering the great cost in skill, effort, and money spent in many months of intensive rehabilitation, it is a tremendous economic and human waste to return the patient to an environment in which he cannot live independently.

Needless to say, all physical disabilities complicate living, but it is the wheelchair that encounters the most restrictive problems in the home. As might be expected, the most frequent architectural barriers are entranceways, bathrooms, the kitchen, and stairways to bedrooms located on an upper floor. As the results of a homemaker training research program over the past 8 years at the Institute of Rehabilitation Medicine, a home planning service has now evolved to assist in the final step of bringing rehabilitation to a productive conclusion, and practical procedures for turning common barriers into functional architectural facilities have been identified to make it possible for the person in a wheelchair to continue to manage independently after leaving the less structurally complicated rehabilitation center.

As with all severely disabled people, in planning for the homemaker, two sets of facts need to be worked out: first, physical limitations of the patient as related to ability to handle a wheelchair, and, second, the problems of the job to be done as related to the space in which to do it. In addition, there are the peripheral but important considerations of finances, family relations, and living patterns.

KITCHEN PLANNING: THE BEGINNING OF THE SERVICE

Because homemaking is a major vocation and the problems of the woman trying to cook from a wheelchair are so obvious, the kitchen was

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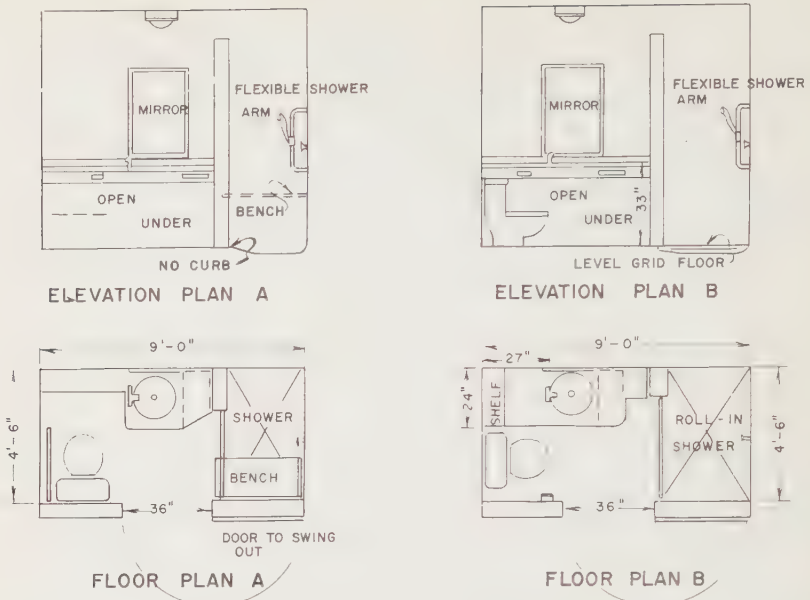
Figure 1. Small wheelchair bathrooms: a 4′6″ × 9′0″ area converted into a small bathroom for independent use. *Plan A*, To be used from a wheelchair by transferring to the toilet and to the shower bench. *Plan B*, To be used with a shower-commode chair that wheels directly into the shower and over the toilet.

the natural first area to attract specialized attention for study and analysis of obstacles.

To begin with, a standard wheelchair measures approximately 4 feet from the front of the footrest to the back of the wheels and is 26 inches wide; standard arms are $29\frac{1}{2}$ inches high. Hence, the low counter required for working in a sitting position should be about 31 inches high and the space below should be left open to provide comfortable leg room. Obviously, this is a change in pattern from the standard kitchen. The second requirement for the cook in a wheelchair is to reduce her need to move the chair to carry items back and forth. Toward this end, the kitchen sink and cooking top should be within easy reach of each other, and there should be a continuous connecting counter on which pots and utensils can be slid rather than carried between these two areas where most of the heavy work of cooking is done. On the basis of these principles, the ideal wheelchair kitchen should be U-shaped, a dead-end wraparound kitchen, wherein the homemaker can maintain herself in one key position. The following are its basic specifications:[1]

The sink and cooktop are located within comfortable reach of each other in a continuous worktop (31 inches high and open underneath for knee and leg room).

One other worktop or pull-out board about 27 inches high is provided for easy cutting, mixing, and chopping.

A wall oven, preferably side-opening, has a pull-out board located directly below it to facilitate handling of hot and heavy pans to and from the oven.

A refrigerator has its door so hinged that it can be approached in the wheelchair, with a counter top next to the open side for loading and unloading, and

with freezer storage located at the bottom of the unit with an easy-opening door.
Ample and easily accessible storage spaces are built for frequently used items.

WHEELCHAIR BATHROOMS: SMALLER, NOT LARGER

The bathroom, commonly the most difficult barrier for all disabled patients, was the next logical area for study. Research in bathroom planning has shown that, as with the kitchen, the same two sets of facts constitute the elements which must be correlated to effectively plan a functional arrangement for independent use by the disabled. This planning should always be done in close cooperation with the rehabilitation therapist who is training the patient in performance of his activities of daily living. Further, since bathrooms and bedrooms are usually located off a hallway, the dimensions of the hall passageway and of the doorways are important in planning to determine whether they are accessible to a wheelchair.

Three different basic wheelchair bathroom designs have now been developed and in actual practice seem to solve most common housing situations. The small wheelchair bathrooms (plans A and B) are very

ELEVATION OF TOILET WALL   ELEVATION OF SINK WALL

FLOOR PLAN   ELEVATION OF TUB & SHOWER WALL
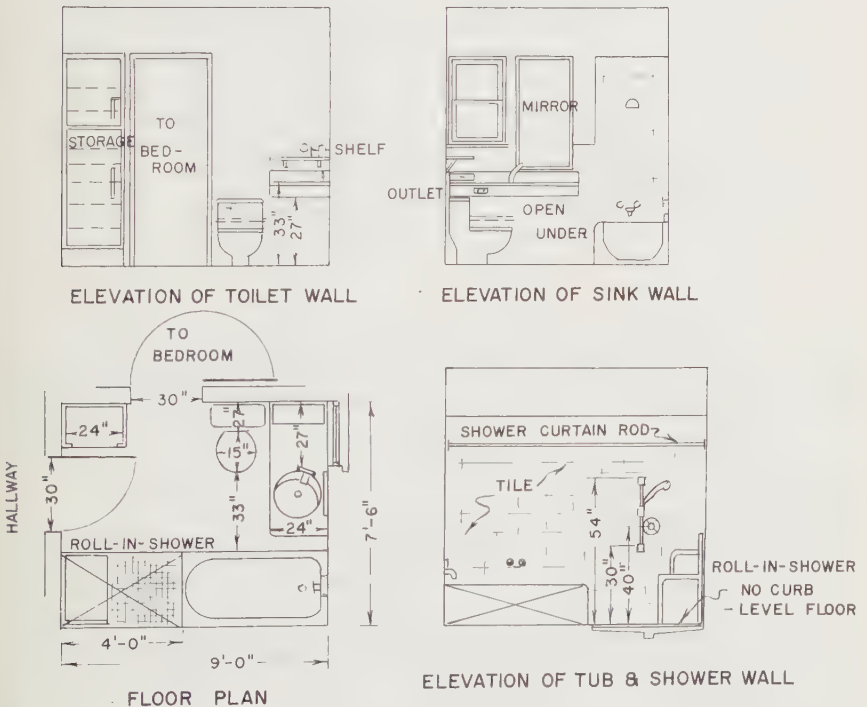
Figure 2.   Family bathroom planned to accommodate the disabled. Designed to be used independently from a wheelchair by transferring to the toilet and to the shower bench, or with a shower-commode chair. The sink is directly in front of the door, to be easily used, and is purposely located to be accessible while the user is seated on the toilet. For the rest of the family, there is a tub with a standard shower. For the disabled, there is a roll-in shower with flexible shower arm, and for those who can safely use the tub, it has been located with ample room for an end approach.

ELEVATION OF TOILET WALL   ELEVATION OF SHOWER & SINK WALL

FLOOR PLAN
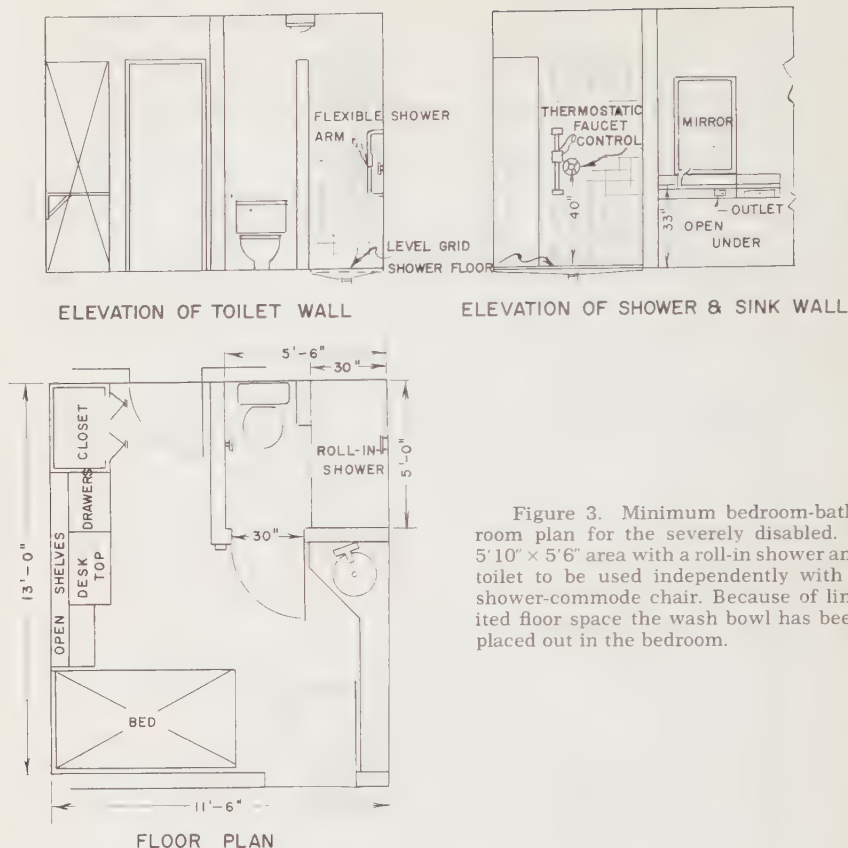
Figure 3. Minimum bedroom-bathroom plan for the severely disabled. A 5′10″ × 5′6″ area with a roll-in shower and toilet to be used independently with a shower-commode chair. Because of limited floor space the wash bowl has been placed out in the bedroom.

practical plans which make use of "borrowed" space taken from the bedroom, an existing lavatory or an adjoining room. The family bathroom (plan C) is a solution for the severely disabled in a one-bathroom house. The minimum bedroom-bathroom (plan D) is useful when it is totally impractical to adapt the existing house and there is no alternative but to add a new room for the patient. The predominating features of these designs are:

A wash bowl placed in a counter top easily accessible from the wheelchair. The toilet positioned properly for transfers.
A shower without a curb, with a stable seat, and located to permit easy transfers.
A door hinged as a safety precaution to open out from the bathroom.
Drawers for storage installed on nylon rollers rather than the usual style of bathroom cabinets.

If the patient is physically unable to perform transfers safely, then a shower-commode chair which rolls over the toilet and directly into the shower should be considered for toileting and showering. Shower-commode chairs of sturdy construction with good brakes are now available that can be safely and independently used by the severely disabled.

To plan a bathroom simply on the basis of spaciousness with ample area for easy maneuverability of a wheelchair is a waste of floor space that people can ill afford. The important principle is the placement of standard equipment in compact relationships that are accessible to the *particular* patient. As a result, many homes can be adapted without necessitating extensive renovations to the entire house.

Though less of a problem, bedrooms also must be planned and re-arranged to permit optimal independence in dressing and bed activities.

House entrance obstacles such as steps and porches may present serious problems by restricting mobility. The conventional entrance ramp is seldom a practical solution because of small lots, defacement of property, and difficulty of use in bad weather. Small electric outdoor wheelchair lifts frequently provide the simplest answer.

THE SERVICE IN TERMS OF THE PATIENT

Home planning evaluation is initiated as soon as a patient's func-tional level can be predicted medically and as early as possible in the hope that home changes will be completed by the time the patient is discharged. Informal consultations with the patient and his family are frequent during all of the planning stages, so that the new arrangements will also be practical for the rest of the family. The home planning con-sultant works closely with the physical and occupational therapists who know how the patient functions. Also, since the social importance of being independent in daily living and its implications for the entire family are now well recognized, the social worker plays an essential part in helping the family to adjust to the necessary changes and stresses the importance of letting the patient manage for himself when he returns home.

The Mechanics of the Service

Because homes vary so widely, it is essential to evaluate each pa-tient's housing individually, and, when possible, a home visit is made to get an accurate picture of the patient's total housing situation and to evaluate the feasibility for changes.

On such a visit, one begins by first taking an over-all look at the plot and house plan, carefully noting the whole house in relationship to the driveway and garage. Someone should be available who knows the house and can identify the locations of plumbing lines and bearing walls, which need to be considered before planning any structural changes. The fastest and most reliable method of getting the dimensions is to have two people, one measuring with a steel rule and the other recording the dimensions in the form of a rough sketch on a pad of $1/4$ inch grid graph paper held on a clipboard. The overall length and width of each specific area are recorded first, and then the locations of the doors, windows, and furnishings. Doorways are always measured from the inside of the frame to the nearest part of the door standing in its open position, which is the narrowest part of the opening. Using approximately one grid square to a foot, the parts of the area can be kept in relatively true proportions to

the whole. From this diagram with its dimensions, an area of the home can be simulated at the hospital. Here the patient practices to determine whether he will be able to function in his wheelchair at home.

When it is not possible to make a home visit, one may establish a working pattern for planning by long distance with the family. A free-hand sketch is made on graph paper from the patient's description of his home, as he remembers it. During this consultation, it is helpful to keep a steel rule handy so that when the question of sizes and shapes come up, it can be used to help in estimating approximate dimensions. From this description, a simple drawing is made and a letter is sent to the family asking for accurate measurements and details and for correction of any mistakes. If perchance the family is planning a new home or an extension to their existing one, suggestions are planned directly on the architect's or contractor's working drawings. The final recommendations, a scale drawing with specifications to implement the changes, must be simple and clear so that prints can be used by the family or sponsoring agency to receive bids and select a contractor for the work.

A WORD ABOUT FINANCING

If finances are no worry, then there is no problem in carrying through with the necessary changes. When only limited funds are available, suggested changes must be planned within the scope of the budget. Where there are no funds and the patient can qualify for assistance under the public program of vocational rehabilitation, the necessary changes may be financed by the state rehabilitation agency. In addition to counseling, diagnostic, and physical restorative services, disabled clients of such an agency are eligible for the training, tools, equipment, and "other goods and services necessary to render a handicapped individual fit to engage in a remunerative occupation." Because home-making is classified as a remunerative occupation, homemakers are thus eligible for these services, including home changes if these make the difference between being employable and being unemployable.

HOME PLANNING FOR MRS. D.: AN EXAMPLE CASE

At the onset of illness, Mrs. D. was a 44 year old wife and mother of two teenage boys. She became a quadriplegic secondary to a cervical spinal abscess. The following suggestions were based on a homemaking-homeplanning evaluation, a home visit, and frequent consultations with both Mr. and Mrs. D. The drawings show the changes recommended for Mrs. D.'s kitchen and for a downstairs bedroom with bath which would make her independent in daily living and let her resume her home-making activities.

THE KITCHEN (Figure 4). On the home visit, it was determined that the rear entrance to the kitchen could be made easily accessible to a wheelchair if a wheelchair lift were installed beside the existing back porch.

In the kitchen itself, none of the existing cupboards, counters, and equipment would be accessible to Mrs. D., so a new "wheelchair kitchen" (31 inches high and open under the counter for leg room) was planned for convenience and the maximum conservation of her limited energy. A comfortable space was also provided for eating in the kitchen. This new plan includes the following features, which have proved to be the most practical for a chair-bound homemaker:

The sink with a single-lever faucet and cooking top with front control panel are located in the continuous counter so that they can both be reached from one sitting position and pots and pans can be slid back and forth rather than lifted and carried between sink and range.

A pull-out board is provided 28 inches above the floor with a hole to secure a mixing bowl for the most comfortable use at this work space.

A wall oven has a side opening door and pull-out board below to facilitate use from a wheelchair.

An electric dishwasher (recommended in this case because it saves so much energy) is 36 inches high and installed to the left of the continuous counter.

The refrigerator has a freezing compartment at the bottom of the box, easily accessible from a wheelchair.
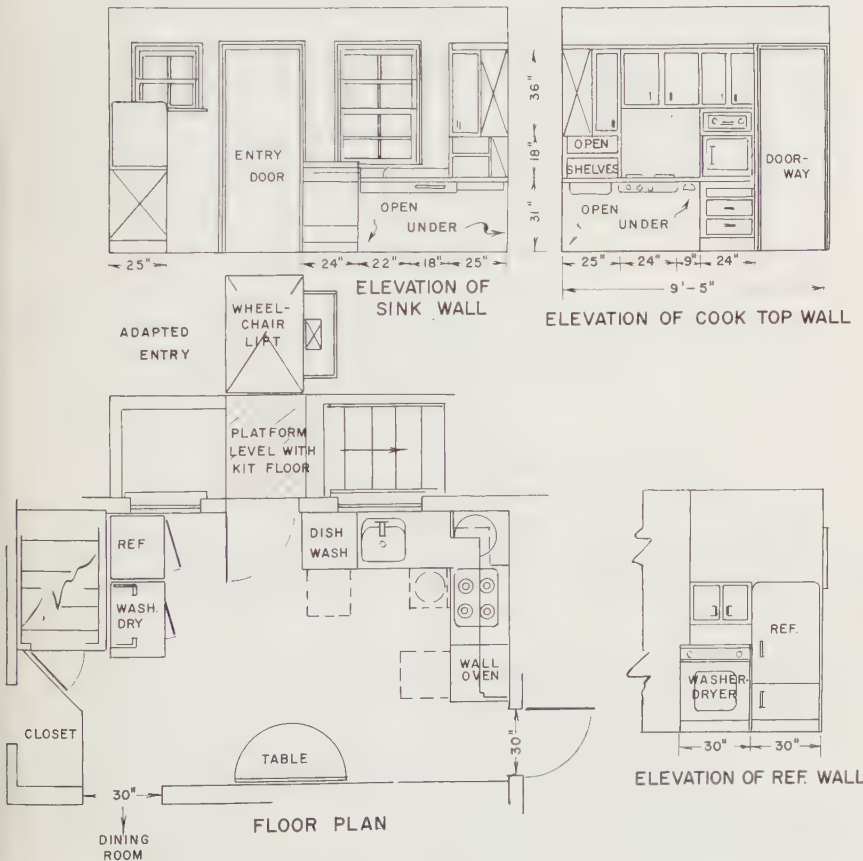
Figure 4. Proposed kitchen changes for Mrs. D.
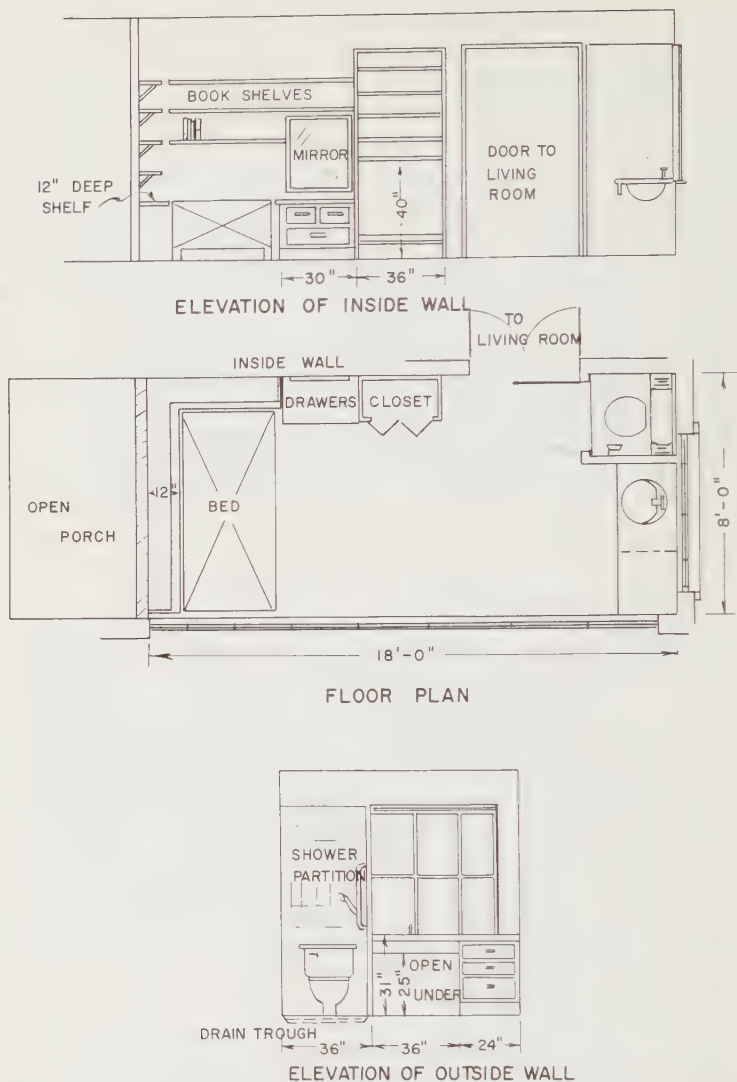
Figure 5. Proposed bedroom-bath plan for Mrs. D. (a), Move open porch wall as shown. (b), Install toilet and flexible shower arm in partition; make sink-vanity top 31 inches high; add shelves, drawers, and closet. (c), Provide electric panel heating and raise floor to level of living room floor.

The combination washer-dryer is front loading and has the controls at the front so that it is easy to use from a chair, and a complete laundry can be done without any lifting of wet and heavy clothes.

Three structural changes were required for this installation. The existing partition and cupboards between the pantry and kitchen were removed, the door to the back apartment was moved about 3 feet to the corner of the kitchen, and the plumbing waste and supply lines were moved to the outside wall in front of the window.

THE BEDROOM AND BATH (Figure 5). With an additional 7 feet taken from the adjoining front entrance porch, the existing small enclosed porch was converted into a practical unit planned for independent living. Before these changes were made, Mrs. D. was sleeping on this porch because it was impossible for her to get upstairs. The open view through the front yard and trees to the street made it a pleasant place, but the cramped room was not winterized, and there were no bathroom facilities.

The plan shows a simple but very comfortable arrangement with shelf space around the bed and easily accessible clothes storage cabinets taking up a minimum of floor space. The washbowl and dressing table shelf with drawers facilitate self-care. The toilet compartment is designed to be used with a shower-commode chair and is planned with a flexible shower arm and special floor drain so that Mrs. D. can use the same space as a shower stall while in a sitting position. (The plumbing waste and supply lines for the upstairs bathroom are conveniently located to tie into the new installation.)

To winterize the space, a new floor with insulation below, about 2 inches thick, brings the finished floor level with that of the adjoining living room, and electric panel heating units are installed in the front window wall. Other structural changes were moving the partition over on the front porch and relocating the entrance.

It was felt that with these changes in the house, Mrs. D. would be able to manage without the services of a homemaker-health aid and resume her own homemaker position in the household. She thus qualified for assistance as a homemaker under the Division of Vocational Rehabilitation in the State of New York, and these home changes were sponsored in part by this agency.

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The Vocational Potential of the Quadriplegic

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For all persons, appropriateness of an employment goal is determined by a variety of factors, including ability, aptitudes, talents, interests, values, and personal needs. With the ill and the disabled, physical and functional limitations are additional factors to be considered and evaluated. It has generally been assumed that there is a high negative correlation between the severity of physical and functional limitation and the potential for successful vocational rehabilitation. This assumption, leading as it does to the conclusion that the severely disabled person has little or no vocational potential, has had a profound impact on the availability of vocational services for the severely handicapped. Vocational rehabilitation agencies have traditionally evidenced reluctance to provide funds and services to persons considered to be poor prospects for successful employment. The severely disabled have in many instances been deprived of education and training and of other services on the basis of arbitrary criteria reflecting lack of essential, specialized knowledge required for a realistic assessment of actual vocational potential.

This paper reports on the vocational potential of patients with one of the most severely handicapping disabilities—quadriplegia. Our purpose is to demonstrate that the severity of physical limitations, per se, is not a reliable index of vocational potential, but that success in vocational rehabilitation is determined primarily by the availability of effective rehabilitation services. Vocational potential, the capacity to attain successful performance in a job, is a function of ability, not of residual disability. The extent of medical and functional limitations may be unimportant or irrelevant if the disabled person possesses or has the ability to learn job skills that are not affected by or not related to his functional limitations. Severe disability, therefore, may have no relationship to physical potential if the disabled person possesses vocationally appropriate abilities, capacities, or skills.

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QUADRIPLEGIA

Quadriplegia by definition is paralysis of all four extremities. It may result from trauma or disease. Traumatic quadriplegia most often is the result of automobile accidents, diving accidents, or falls. Quadriplegia may also result from disease of the brain, of the spinal cord, of peripheral nerves or muscles.[5,8] This paper will confine itself to the traumatic and polio quadriplegic.

Traumatic quadriplegia most often is caused by fracture-dislocation of one or more cervical vertebrae with resultant injury to the spinal cord. The extent of paralysis and of functional and sensory loss depends on the level of injury to the cord and the degree of damage. The most frequent level of cervical fracture-dislocation is at the fifth and sixth or the sixth and seventh vertebrae. In polio quadriplegia there is no sensory loss and no loss of bowel and bladder control, as there is in traumatic quadriplegia.

AVAILABILITY OF EFFECTIVE REHABILITATION SERVICES

Medical and rehabilitation personnel who are unfamiliar with the rehabilitation of quadriplegics are overwhelmed by what seem to them drastic limitations that preclude the possibility of independence in most activities of living and that, perforce, rule out the goal of competitive employment. Furthermore, the quadriplegic patient, himself ignorant of the progress in quadriplegic rehabilitation and unaware of his potential, accepts these limited goals. Only 10 years ago, the quadriplegic was rarely served by vocational rehabilitation agencies, which assumed that their disability ruled out the possibility of successful employment. An article published in 1961[10] stated that rehabilitation personnel frequently feel "that there is nothing these patients are able to do." Today, increasing numbers of quadriplegics are in competitive employment in an expanding spectrum of occupations. Through research, innovation, and improved programs, it has been possible to overcome obstacles to job performance which had previously been seen as insurmountable barriers.

However, despite the development of a body of knowledge that has been successful in rehabilitating quadriplegics into employment, there is still a substantial segment of the quadriplegic population that does not receive the benefit of this knowledge. A recent survey of the services provided to paraplegics and quadriplegics in three states indicated that they generally receive a narrow range of services, with relatively few having the benefit of help from professionals with specialized training in spinal cord injuries.[9]

Successful rehabilitation into employment generally requires the efforts of a rehabilitation team with the specialized experience and knowledge required for dealing with the medical, social, psychological, economic, educational, and vocational problems of the quadriplegic. Depending on the nature of the quadriplegic's problems, the team may include some or all of the following professionals: physician, psycholo-

gist, psychiatrist, social worker, occupational therapist, physical therapist, nurse, rehabilitation counselor, orthotist, and placement specialist. The industrial engineer and biomechanical engineer may also contribute to the solution of vocational problems.

ASSESSMENT OF VOCATIONAL POTENTIAL

In exploring and assessing vocational potential, quadriplegics cannot be considered a homogeneous group. Residual function, depending as it does on the level and extent of spinal cord involvement, varies from person to person. The nature of treatment, the type of self-help devices, special equipment required, the potential for self-care and for vocational activity, will all be determined by the patient's unique pattern of motor function. These factors will define his ability in activities such as feeding, grooming, writing, typing, dressing, turning the pages of a book, transferring between wheelchair and bed, and into an automobile, and driving an automobile.

In evaluating vocational potential, and in defining realistic employment goals and employment environments, a variety of factors must receive attention and study. The rehabilitation counselor and the placement specialist, in assessing the quadriplegic's suitability for employment and for a specific job, will evaluate a variety of tasks that are often required for employment, such as ability to handle pen and paper, telephone, typewriter, etc. The type and height of the desk and the ability to use and manipulate other types of equipment will be explored. Here, the combined efforts of the rehabilitation counselor, occupational therapist, and engineer may be successful in developing a working area and equipment to enable the quadriplegic to perform, successfully, a variety of job duties.

The tests that have been developed for the assessment of vocational potential are generally subject to substantial error in predicting the vocational success of a particular person. Neither for the able nor the disabled population do we have measuring instruments on which we can generally rely. In working with the severely handicapped, the counselor and rehabilitation team are confronted with a challenge that may not be met successfully by the routine attitudes and procedures that are successful with less limiting conditions. Imagination and innovation are the essential ingredients of successful vocational services. Only through an effective use of these ingredients can one hope to give the severely disabled patient the opportunity to achieve a vocational goal that makes use of his highest potential.

EMPLOYMENT OF QUADRIPLEGICS

There have been few published reports on the employment of quadriplegics. A survey by Bors[1] showed only 8 per cent gainfully employed. Walker[10] states that the limited information on quadriplegics indicates that they are employed in every major occupational category, but that the bulk are employed at home in vocational objectives that are often unsatisfactory.

The Institute of Rehabilitation Medicine in a previous follow-up study[x] obtained data from 177 out of a total of 355 quadriplegics who had been admitted to the Institute between 1948 and 1960 and found that 69, or 39 per cent, of the 177 were employed, and 18, or 10 per cent, were in college. Ninety, or 51 per cent, reported that they were unemployed. In a Canadian study[1] of the vocational rehabilitation of 343 quadriplegics, 34 per cent were employed and 10 per cent were in school or in training.

A more recent follow-up study at the Institute of Rehabilitation Medicine covered 143 quadriplegics admitted to the Institute between 1962 and 1967. Only patients between 18 and 60 years of age were included. No data were available for 12 patients. Of the 131 patients on whom information was obtained, 34 per cent (44 patients) were in competitive employment, 2 per cent (3 patients) were homemakers, and 47 per cent (62 patients) were in college or in special vocational training programs. Only 17 per cent (22 patients) were unemployed. Of the 44 in competitive employment, 36 worked in regular places of employment, five performed all or some of their work at home, and the remaining three operated small businesses. Of the 62 in educational programs, 59 were in college and three in vocational training programs. Our experiences with quadriplegics possessing a college education indicate that quadriplegics who successfully complete a college program have excellent prospects for successful competitive employment. It might be expected, therefore, that about 80 per cent (i.e., the 44 currently employed plus the 62 in educational programs) will eventually enter into competitive employment.

Quadriplegics have generally found employment in the professional, technical, managerial, sales, and clerical areas, occupations that can be successfully performed with minimal manual abilities if the person possesses the intellectual and educational qualifications. The quadriplegic, however, who does not qualify for these occupational areas is still an unsolved challenge to the vocational rehabilitation specialists. A few quadriplegics have been successful in manual types of occupations, but very little has been done thus far to develop a program of research and service that might solve the vocational problems of this group.

Since 1951, the California Department of Rehabilitation has sponsored a special program of services for the severely disabled, including over 110 quadriplegics. The recommendations flowing out of their work[3] point to a path that can lead to more successful vocational rehabilitation for the quadriplegic. Essentially it is the availability of experts, time, money, and effort within the framework of a philosophy that "sees things not as they are now, but as they could be."

Another approach to the problem is being made by a group at the Texas Rehabilitation Center of the Gonzales Warmsprings Foundation. This project's aim[1] is "to determine the extent to which quadriplegics can be made vocationally productive by manipulation of the environment to maximize their abilities." The project's facilities include a hospital with special facilities for treatment of quadriplegics and a vocational

workshop. This project has explored such vocational activities as envelope stuffing, mailing, and industrial ceramics. The experience of this project reveals the difficulties in developing suitable employment for this group, but also offers hope that with further exploration and innovation the occupational opportunities for quadriplegics can be expanded.

THE CHALLENGE OF THE SEVERELY DISABLED

It is beyond the scope of this article to describe the technical aspects of an effective program for the rehabilitation of quadriplegics. Successful rehabilitation requires the coordinated services of many disciplines working together. Each participating profession brings to the rehabilitation team its own body of professional skills. However, in order to achieve optimal goals with the quadriplegic, each profession must acquire the specialized knowledge and skills required for the effective resolution of the problems of the quadriplegic. As Walker[10] points out, "In reality, the inabilities of patients to achieve appropriate goals do not represent failures by the patient, but by rehabilitation personnel who have not developed technics and programs which tap patient resources. Patient failures cannot be justified on the basis of rationalization that such severely disabled patients cannot work."

Quadriplegics and other severely disabled persons are demonstrating in increasing numbers that when effective rehabilitation services are available they can successfully enter into employment. With our current knowledge and techniques many more could achieve success in employment if they were given the opportunity to make use of an effective rehabilitation program. Rehabilitation, health, and educational personnel in every profession providing services to the disabled must in increasing measure become aware of the vocational potential of the severely disabled and of the specialized services required to ensure that the severely disabled are given the opportunity to realize their full potential for work and for employment.

SUMMARY

This follow-up study covered 143 quadriplegics discharged from the Institute of Rehabilitation Medicine between 1962 and 1967. Patients between the ages of 18 and 60 who were residents of the United States were included in the study. There were 132 patients who were quadriplegic as a result of trauma and 11 as a result of poliomyelitis.

Of the 143 patients contacted, data was obtained from 131. Of this group, 44 or 34 per cent were in competitive employment; 2 per cent (3) were homemakers, and 47 per cent (62) were in school. Only 17 per cent (22) were unemployed. Of the 44 persons in competitive employment, 36 worked in regular places of employment, five performed all or some of their work at home and three operated small businesses. Of the 62 individuals in schools, 59 were in college and three were in vocational training programs. The college students were enrolled in 45 different

colleges. Our experience with quadriplegics who have successfully completed a college program indicates that this group has a highly successful employment record. One can expect, therefore, that up to 80 per cent of the quadriplegics in the group studied will eventually enter into employment.

Previous reports on the employment of quadriplegics have generally found that most quadriplegics were in homebound types of employment. The present study, however, demonstrates dramatically that with proper rehabilitation services, quadriplegics can qualify for employment in competitive industry.

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The Future Role of Rehabilitation Medicine in Community Health

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Well and ill may be considered the two polar conditions of the state of man's health, with the spectrum between the polar sites representing gradation from perfect health to complete absence of health or death. The World Health Organization defines health as a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity.[5] Health, claimed Perkins,[2] is a state of relative equilibrium of body form and function which results from its successful dynamic adjustment to forces tending to disturb it. It is not a passive interplay between body substance and forces impinging upon it, but is an active response of body forces working continuously toward readjustment.

The above definitions are in accord with the concept of the health spectrum. Rogers' Health Status Scale,[5] often used in the public health field, clearly demonstrates this concept (Fig. 1). A state completely free from illness is termed optimum health; suboptimum health is the transient state between optimum health and overt illness or disability, and death is the final phase. There is little difficulty in distinguishing between life and death, but the subtle distinction between illness and health is often more difficult to detect.[5] Conceptual recognition of suboptimum health poses no question, but clinical identification of suboptimum health may not always be easy. Infectious disease with an extremely long incubation period, such as Hansen's disease, is a good example. However, it has been found that such obscure conditions can often be detected at the suboptimum state through careful surveillance of the high-risk population.

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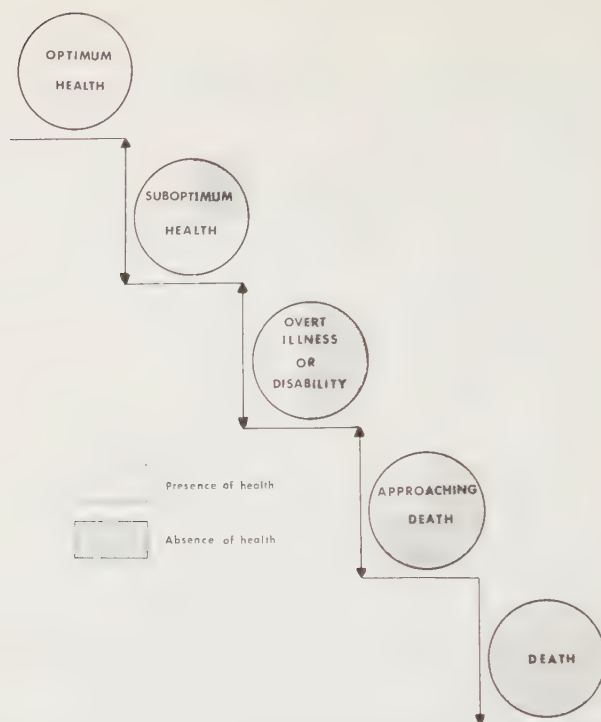
Figure 1.   Health status scale. Arrows indicate the direction of changes in health status. (Modified from Rogers, E. S.: Human Ecology and Health. New York, The Macmillan Co., 1960.)

Man's health status, not being static, changes from day to day or even minute to minute in an upward or downward direction. For example, a man with a strong immunity can maintain optimum health in spite of bacterial invasion. Without immunity, his health status may drop as far as overt illness and then, through various defense mechanisms or treatment, eventually rise or return to optimum health. Conversely, in a case of severe septicemia, it may fall to approaching death. At no time during this process does the status of his health remain stationary.

This concept may also be applied to disability. Amputation of a lower extremity is not an inevitable consequence of diabetes mellitus, as this is not a disease directly affecting the lower limb. At the onset of illness, the limb is in optimum health and the patient in suboptimum health. If the disease is not treated or is ill-treated, arteriosclerosis and peripheral neuritis may develop; thus the limb descends to suboptimum health. Then trauma produces local ischemia with resultant diabetic gangrene, and the limb and patient are both in the overt illness phase. When amputation becomes necessary, both patient and limb fall to the approaching death stage. Amputation equals death of limb. However, the postoperative patient rises to the overt illness status. Finally, the diabetes is well

controlled but the patient, who would otherwise be considered as returned to suboptimum health, remains at the overt illness level, due to disability, until prosthetic rehabilitation is successfully completed.

The foregoing illustration reveals that this and other public health concepts could, with circumspect development, be applied to disability and could disclose a new frontier of challenges and concerns for rehabilitation medicine.

NATURAL HISTORY OF DISEASE

The concept of a single cause of disease gained momentum with the coming of the bacteriological era, and causes relating to the host and the environment were often forgotten in the enthusiasm for isolation of specific agents.[27] After this enthusiasm subsided and further public health experience and knowledge were accumulated, a combination of three elements, *host, agent,* and *environment,* was recognized as the causation of illness.

The human host has numerous characteristics which are regarded as causative factors. Those most often enumerated are age, sex, race, habits and customs, education, marital status, occupation, body constitution, heredity, immunity, and psychological characteristics. Agent factors may be classified, roughly, into biological, genetic, chemical, nutrient, physical, and mechanical. Environmental factors include the physical, the biological, and the socioeconomic.

The crux of this concept, multiple causative factors of illness, is that unless all three elements are peculiarly and specifically fulfilled, ill health and disability cannot exist or be created. A unique interaction of these three elements produces a disease condition. Because of the importance of this triad (Fig. 2) to an understanding of ill health, let us examine the interaction of the causative elements in fractures.

"Fracture of the neck of the femur is commonly seen in elderly people, mostly women,"[22] is an acceptable statement among clinicians. This statement, however, identifies only two host factors, age and sex. One group[1, 11] reports high prevalence of hip fracture among white women, while Robey[34] disagrees in his 99 Negro cases. Both studies include a third host factor, race. Women customarily wearing bedroom slippers tend to shuffle and stumble; this would add a fourth factor, habit. Consider, further, the possibility that body weight, physical and occupational activity, balance, forgetfulness, clumsiness, carelessness, medication, poor vision, and myriad other factors could also be peculiar to the host.

Waxed or wet floors, rugs, telephone or electric cords, toys on the floor, poor lighting, icy steps or walks may be among the many physical factors peculiar to the environment that, combined with host factors, result in a fall. The sagging stairs and crowded, cluttered apartment of an old tenement building represent physical environmental factors, but the socioeconomic factors cannot be ignored.

The agent in the causation of fractures is force. Mechanical in nature, force exerts unusual stress on the body mechanisms.[12] The body
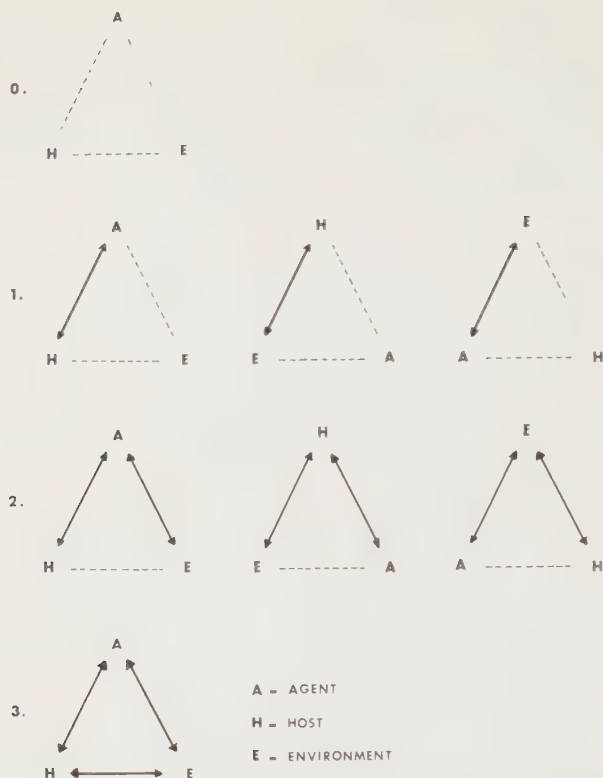
Figure 2.   Production of disease stimulus. Unless host, agent, and environmental factors interact simultaneously, a disease stimulus will not be produced. A solid line with arrows and a broken line indicate presence and absence, respectively, of interaction between two of these factors. Models 0, 1, and 2 show partial or no interaction. Only model 3 can produce a disease stimulus.

is unable to make a successful adjustment to the force which disturbs it; therefore, the fracture occurs.

In the natural history of a disease, the time at which all three causative elements are present is called the period of prepathogenesis. During this period there is one point wherein all factors interact and produce "disease stimulus" and evolve into the period of pathogenesis. Finally, the disease progresses to the clinical horizon (Fig. 3). Entering the period of pathogenesis does not necessarily mean a man is ill; there may be a subclinical stage. In this stage, the three elements continue to interact and there may be regression to prepathogenesis or progression to the clinical horizon. In the case of trauma, there is no subclinical stage. Once the disease process reaches the clinical horizon, it is recognizable upon clinical examination.

The disease may progress to death, remain in the period of pathogenesis, or regress to the prepathogenesis period. This concept of the natural history of disease is relevant to any trauma or disease condition and is consistent with the health status scale.
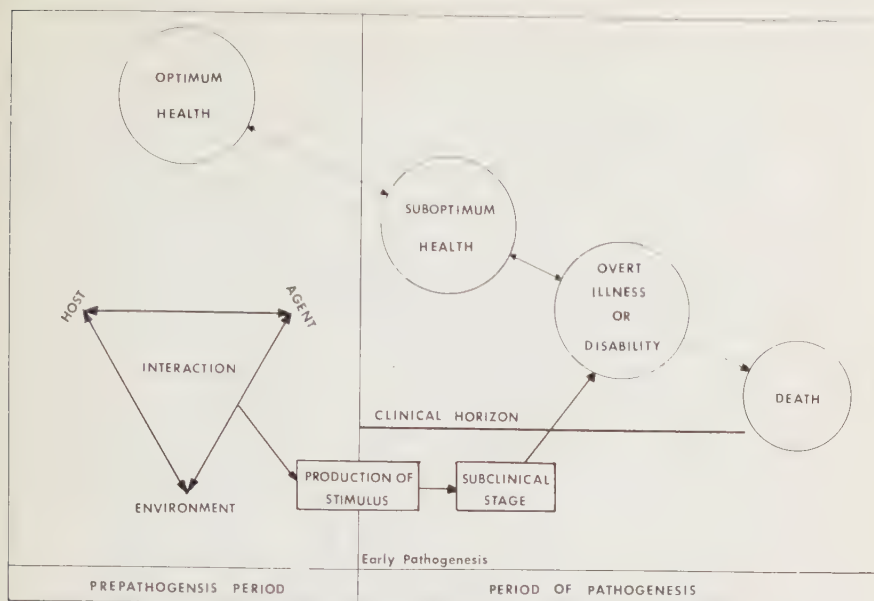
Figure 3. Natural history of a disease in man. The natural history of a disease is consistent with the health status scale. If a man recovers from the subclinical stage, the process is from suboptimum health directly to optimum health.

LEVEL OF PREVENTION

Public health and clinical medicine have, traditionally, focused on different phases of man's health status. Their ultimate goal is to maintain man in optimum health or in the period of prepathogenesis.

Public health, historically, concentrates on preventing optimum health from changing to suboptimum health or overt illness, or preventing development from prepathogenesis to the clinical horizon. This is termed primary prevention (Fig. 4), which is divided into health promotion and specific protection. It covers such operations as health education, improvement of environmental conditions, immunization, and surveillance of the high-risk population. Clinical medicine pursues secondary prevention through early diagnosis and prompt treatment; disability limitation and rehabilitation are classified as tertiary prevention.

More recently, public health became concerned with delivery of better health care to the patient and the community. Genetic counseling, fetology, or even diagnosis by amniotic tap[16] have become important parts of clinical medicine. What is significant is that public health has enlarged its scope to include overt illness, and clinical medicine has become involved in optimum or suboptimum health.

We have discussed the health spectrum and explained the fluid nature of health and illness. In contrast, the levels of prevention have

PREVENTION

PRIMARY

1. HEALTH PROMOTION

2. SPECIFIC PROTECTION

SECONDARY

1 EARLY DIAGNOSIS

2. PROMPT TREATMENT

TERTIARY

1. DISABILITY LIMITATION

2 REHABILITATION
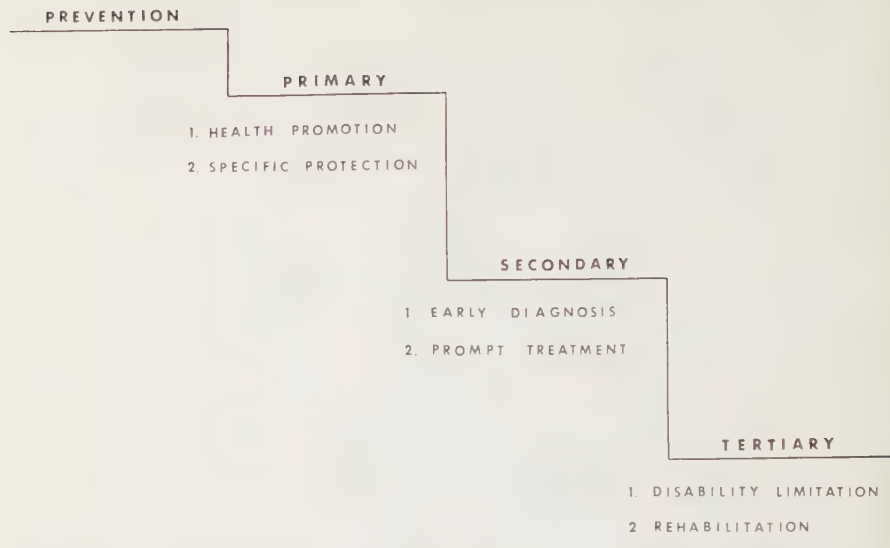
Figure 4. Levels of prevention. (Adapted from Columbia University, School of Public Health and Administrative Medicine, Epidemiology Division. The original model shown in "Preventive Medicine," Leavell and Clark, McGraw-Hill Book Co., 1958, classified Disability Limitation under Secondary Prevention.)

been compartmentalized into strict, well-defined areas of responsibility. The rigidity of the latter appears incompatible, as health concepts and health care change. The roles of public health and clinical medicine need to be redefined accordingly.

COMPREHENSIVE HEALTH CARE

Comprehensive health care is defined as care that is provided to the patient according to his needs in appropriate, continuous, and dynamic patterns.[11] This is "an operational definition that tells us what to do rather than what to say, that makes us aware of things, facts, experiences, and the way they are related in the real world."[24]

"Comprehensive" is interpreted broadly and covers all essential aspects of prevention, clinical care, and rehabilitation throughout the life span for all segments of society.[12] The priority in comprehensive care is meeting the individual need and assisting in the attainment of individualized goals; stereotyped medical care becomes obsolete.

The task in public health is to insure sound treatment in the facility best suited to the patient's need.[19] "Appropriate pattern" refers to selection of these facilities to implement the treatment. Hilleboe[19] recognizes four types; the patient's home, the hospital, and facilities for either out-patient treatment or long-term care. Whatever the illness and need may be, these four types of facilities must be utilized in the most comprehensive, efficient, and economical way possible to insure maximum patient and community benefits.

"Continuous pattern" indicates uninterrupted, coordinated treatment. When care is provided by several facilities, each must, without interruption, augment the previous one, or the time and skills invested by the previous facility are lost. This is a very tangible loss to the patient and to the community which supports these medical services. The effectiveness of continuity of care can be measured by the final achievements of the patient, his family, and the community.[1]

Lastly, "dynamic pattern" must be emphasized. Webster's Seventh New Collegiate Dictionary defines dynamic as "marked by continuous, usually productive, activity or change." In order to maintain a dynamic pattern of health care, we must relinquish the old conventional concepts. Medical care today does not limit itself simply to the patient-doctor relationship. In reality, this is only a fraction of the total problem. Medicine, as the guardian of man's health, must be concerned with and strive for improvement of the entire community milieu. It has been stated that present care, at best, maintains chronically ill and disabled persons in the community at minimum levels of survival.[25] If this criticism is just, then, "comprehensive health care" is of major significance to rehabilitation medicine.

FUNCTIONAL DIAGNOSIS AS AN EPIDEMIOLOGICAL SCHEME

Not infrequently, one hears a young resident physician saying lightly, "Just a *routine hemi case.*" The "routine hemi" notion is a unilateral motor paralysis following a characteristic episode and carries with it overtones of "uninteresting case." As a result, treatment will undoubtedly be a "routine hemi program," probably followed by a "routine discharge." This is a classic example of the oversimplification, ignorance, preconceptions, and generalizations which plague society in this century. Because of an extremely limited frame of reference, no differentiation is made between the host and environmental characteristics of one hemiplegic and those of any other. Though clinical pictures may be identical, the other variables must be considered in order to provide a true portrait of the patient. What is important is not so much the difference in symptoms but the difference in men.

A clinical diagnosis such as right hemiplegia due to left middle cerebral artery thrombosis – or even "352" and "332," expressing hemiplegia and cerebral thrombosis, respectively[16] – tell us only what happened to the patient. Unfortunately, most medical records and case histories are no more illuminating, and do not indicate the physical, mental, or socioeconomic ability of a man.[10] The inadequacy of clinical diagnosis has been apparent for several decades to those who treat the physically handicapped. Out of the need for a more complete expression, a concept of functional diagnosis or functional classification has emerged.

Various methods of determining degree of disability devised in the first half of this century related primarily to the type of injury implicated

in liability and workmen's compensation cases.[7, 10, 17, 29, 47] Most authors recommended that disability be evaluated on a functional and anatomical basis[18] in order to maintain the utmost objectivity.

On the other hand, there were many attempts to assess disability by measuring capacity to perform physical tasks.[6, 20, 26, 28] Such methods emphasize total physical ability to perform practical activities necessary to daily living rather than anatomical function. A similar approach has been used for evaluation of cardiac patients.[15] Moskowitz and McCann[30] proposed a unique method of disability evaluation adapted from the Physical Profile System of the Canadian and United States Armies.[9, 13] The merit of their system, known as PULSES, is its simplicity and its inclusive expression.

Comparison of these methods in terms of objectivity, reproducibility, reliability, or practicability is not in order. As intended, each method expresses physical ability in varying degree and some include emotional and mental status. However, if rehabilitation medicine is to render service within a framework of comprehensive health care, assessment of physical ability alone is not sufficient. Sokolow and associates[38, 39] developed a form for classifying emotional, social, and vocational capacities as well as physical ability. This type of evaluation presents a new concept for functional diagnosis of the disabled.

The ideal functional diagnosis should define patient need and suggest prognosis. "Function" is not interpreted as somatic function but as ability to live in society in a dignified and, if possible, productive manner. It will not discount the physical disability evaluation because that, too, influences the destiny of the handicapped. However, the ultimate destiny of the handicapped lies in the availability of appropriate, continuous, dynamic rehabilitation services, developed out of creative professional exploration into every avenue of patient need.

An epidemiological approach to functional diagnosis is the first step in this direction, as it provides an analysis of the host, agent, and environmental factors involved in disability. An assessment of this kind of data could furnish wider, more basic knowledge from which to create more individualized and advantageous facilities and services and a scientific approach to prevention of disability. Rehabilitation medicine, as the authority on disability, should assume leadership for eradication, wherever possible, of conditions responsible for disablement.

With a system of epidemiological functional diagnosis the range of data collection becomes wider; consequently, methods of evaluation and scoring may become cumbersome and involved. We must, somehow, surmount these obstacles and evolve a simple method of expressing epidemiological functional diagnosis in order to maintain a pertinent and relevant perspective to health practice in the future.

REHABILITATION + INVESTMENT = DIVIDEND

The relationship between health and economy or, more correctly, illness and economy, has been an interesting subject for economists as well as physicians since the day of Edward Chadwick.[11] Literature on

this topic is voluminous. Morbidity seems to relate to the economic strata of a population, although it is difficult to establish a one-to-one relationship.[2] The economic effect of illness-absence on industry is becoming an acute problem in highly industrialized and democratic countries such as the United States.[8]

During the fiscal year 1963, the people in the United States spent 34.3 billion dollars for medical care, related services, and supplies. Two thirds, or 22.5 billion dollars, was attributed to the major diagnostic groups. It is astonishing to note that, although the total loss to gross national product in 1963 due to premature death, all illness, and disability was estimated at 23.8 billion dollars, only 11.5 per cent was attributed to mortality.[33]

Berkowitz's summary[3] describes the public policy behind the Vocational Rehabilitation Act clearly and forcefully:

> The first Vocational Rehabilitation Act, as well as subsequent vocational rehabilitation legislation, appear to have been based upon these ideas:
>
> (1) The notion that everyone has a right and need to work and that this is the basic ingredient of American culture.
>
> (2) That America needs the productive effort of all its citizens.
>
> (3) That disability results in costly dependency. Rehabilitation reduces dependency.
>
> (4) The concept that rehabilitation is important because it makes disabled people more effective and efficient consumers.
>
> (5) Specialized agencies and specialized programs are required to prevent disabled people from being neglected in programs designed to serve anybody.

In spite of statistics which prove that illness and disability are more costly than health and regardless of forceful philosophical interpretation, some sectors of the population do not acknowledge the economy of this approach.

"We have great problems of unemployment among healthy people in our country; we cannot afford to worry about vocational rehabilitation of disabled people," is a common argument voiced by some developing nations. This may be a legitimate statement for a nation whose economy is faltering, but it is heard almost as often in the United States. The least convincing reply to the disbelievers is an exposition about humanity or the rights of man, but usually the full range of economic arguments prove effective in our profit-oriented society.

Not every disabled person can be restored to employment, as some remain too disabled to be productive. A husband may not be able to earn a livelihood. But if treated and able to function at home, his wife can go to work. If he is not rehabilitated, his wife has to stay home and the family becomes a public charge. The only other alternative is to place him in a public chronic care facility. Though patients may not continue to contribute directly to the national economy, they can maintain family earning power and prevent increased public expenditures.

However, reaching the unrehabilitated patient is not reaching the total problem. There are other hard-core realities which rehabilitation medicine must face. Delays in completion of rehabilitation training, even the haphazard "routine program" or the hasty "routine discharge" can place additional financial burdens on the community. As public and

private medical costs soar, resources have to be judiciously utilized to provide maximum care to maximum numbers of patients. Rehabilitation medicine must invest its skills and facilities in the most profitable manner possible.

Since rehabilitation medicine is a direct or indirect contributor to the national economy, further assessment of rehabilitation should include cost-benefit analysis.[44]

PREVENTIVE REHABILITATION

Rehabilitation may be defined as "the ultimate restoration of a disabled person to his maximum capacity – physical, emotional, social, and vocational"[36] and indicates that the primary concern of rehabilitation medicine is the disabled person. Disability is the resultant of a congenital condition, disease, or trauma. Once a person becomes disabled, his physical impairment, such as hemiplegia, paraplegia, or amputation, is stable; but his physical function is not always static. The improperly treated patient will develop additional disabilities which were not present in the initial physical impairment. This is often termed secondary disability, and prevention of secondary disability is a priority of rehabilitation medicine.[37]

In recent years, the term "preventive rehabilitation" has been used in the field of leprosy rehabilitation.[21, 23] Leprosy frequently results in severe disabilities and deformities, particularly of the hands and feet. However, in the early stages of the disease, no disability or deformity exists. Improper treatment and the carelessness and ignorance of patients gradually produce disabilities and deformities that are often irreversible. Once these conditions set in, a highly skilled surgical and rehabilitation team and elaborate facilities are required. Sadly enough, these are the disabilities and deformities that are the cause of prejudice and stigma. It is now known that proper medical treatment, modifications in activities of daily living, and simple home exercises can prevent these deformities and disabilities. Consequently, prevention of physical disability prevents psychological and social disability. "Preventive rehabilitation" along with physical, social, emotional, and vocational rehabilitation became a component of the leprosy control program.[31] "Preventive rehabilitation" means preventing disability of any kind and it is medically and socially more satisfactory and economically more sound.

Some may contend that preventive rehabilitation is not within the province of rehabilitation medicine but in that of preventive medicine. If this debate is valid, then pediatricians should not vaccinate children, nor should obstetricians be concerned about German measles, and certainly public health officers need not be concerned with delivery of medical care. The fact is that the trend in present health care practice is toward clinical practitioners playing wider roles in preventive medicine and public health officers assuming more responsibility for delivery of medical care to the population. The idea of preventive rehabilitation is the timely and pertinent consequence of current health trends.

This does not suggest a change in the concepts of rehabilitation medicine, but rather that the scope of rehabilitation will be enlarged to embrace all of the preventive aspects of disablement. Acceptance of this challenge proclaims our determined effort to decrease the endemicity of physical disability.

COMMUNITY REHABILITATION TEAM

Rehabilitation medicine, more than any other speciality, extends beyond the scope of conventional medical and hospital care. White-house's statement,[48] "Rehabilitation is cultivation, restoration, and conservation of human resources," is characteristic of the collective effort which is fundamental to successful rehabilitation.

"Teamwork" was the original and unique approach which rehabilitation brought to medical practice. Teamwork characterized the relationship and interaction of medical and paramedical professionals in their effort to restore the disabled. As the concept of comprehensive health care emerges, teamwork in rehabilitation medicine gains a new posture and significance.

There are many examples of successful restoration in one site and subsequent failure in another. The amputee who leaves the prosthesis in the closet is representative and so is the aphasic who, though trained to speak, returns to a lonely existence and lapses into primitive grunts. These illustrations demonstrate that teamwork in the hospital is not enough. We must reach out into the community in order to preserve and enhance the accomplishment of the hospital team.

If comprehensive rehabilitation care extends into the community, then the community and its government, public and private health and welfare agencies, business and industry, religious institutions and civic organizations can no longer be considered as "outside resources" to be tapped whenever indicated. The hospital-based team joins those instruments previously labeled "resources" and all become active participants on the community rehabilitation team. The hospital-based team continues to function as it always has in the rehabilitation center but, by virtue of its expertise, is the catalyst for the new community rehabilitation team.

The responsibility of the community rehabilitation team is to plan, coordinate, and execute community-based programs and services for the handicapped and play a dominant role in planning for the future, so that all communities will possess those facilities and services which will enable the handicapped to participate and function with dignity in every aspect of community life.

REHABILITATION MEDICINE IN COMMUNITY HEALTH

The classic model of personal health care is divided into (1) primary prevention: public health; (2) secondary prevention: clinical medicine; and (3) tertiary prevention: rehabilitation. There are both preventive and therapeutic aspects in each level of prevention. The advancements

in modern medical care demands a more flexible interpretation of prevention.

Any attempt to bring man toward optimum health may be conceptually termed rehabilitation. Thus, according to the definition of rehabilitation, all clinicians practice "the act of rehabilitation." In most instances this could not be considered tertiary prevention. Likewise, rehabilitation may be involved in surveillance of a high-risk population and though this is certainly primary prevention, it is not public health. Any specialty in medicine may, by necessity from time to time, function at a level of prevention other than the one to which it is assigned. Any effort to halt deterioration of health may be called prevention and be at variance with the classic model. Consequently, the model has value only when it is interpreted flexibly and realistically.

The approach of rehabilitation medicine — treating the patient as a whole person, working in a team, trying to restore the patient to maximum function, and attempting to prevent further disability — is unique in clinical medicine. However, if rehabilitation medicine confines itself exclusively to the technology of restoring the disabled, its future becomes very limited and, indeed, quite dim. In the past two decades, rehabilitation medicine grew from infancy to maturity; yet it is still a newcomer to the medical community. Despite this, it has been tremendously active in promoting legislation for disabled adults and children and for the care of the elderly. It has gained wider acceptance for the disabled and opened doors heretofore closed to the handicapped worker. But it has not been as vigorous in the domains of prevention, health education, and community planning.

The physiatrist's work is intrinsically that of a generalist, because it coordinates and overlaps the activities of several professionals. The expertise of rehabilitation medicine has a great deal to contribute to the general health and welfare of the community while it continues to serve the handicapped individual.

Comprehensive health care necessitates action on many fronts. The appropriateness of our facilities such as nursing homes and extended care institutions need re-evaluation; their stuporous aspects must be eliminated and more stimulating environments introduced. Better utilization of home care or visiting nurse services could promote continuity and more dynamic care in the home. The ordinary, daily routine activities of rehabilitation medicine services must be reassessed in depth. The rehabilitation centers and the community must jointly revise concepts and re-program their activities to provide more realistic and more satisfying services.

The introduction of epidemiological functional diagnosis and preventive rehabilitation will disclose frustrating limitations in hospital-based rehabilitation services. The community-based rehabilitation medicine service, typified by the community rehabilitation team, can diversify its functions. Disability prevention clinics could be active in primary prevention, diagnosis and treatment of environmental conditions, surveillance of the high-risk population predisposed to disability, and intensive health education for prevention of disability. They would also

provide maintenance treatment for the disabled in the community, with special emphasis on prevention of secondary disability. Epidemiological exploration suggests the need to create a new type of health care to prevent home accidents among the elderly. Environmental hazards in housing should no longer be the impregnable domain of building inspectors, nor construction solely the domain of architects. The manifold problems of the disabled can only be solved by the manifold efforts of the community and rehabilitation medicine.

The role of the physiatrist shifts from being hospital oriented to being community oriented. Being a generalist, and being aware of the total problem of the disabled, the physiatrist is the professional best equipped to guide the community rehabilitation team. His professional skills, insight, and creativity must be utilized to influence community and civic planning, urban renewal, business, new construction, the creation of new services, legislation, and public opinion. Every community effort, whether for the disabled or not, must recognized that the handicapped, as citizens, are entitled to freedom of access and opportunity. Rehabilitation medicine must make this contribution to the city of tomorrow.

The hospital and community-based rehabilitation services will contribute their different perspectives to promote complete physical, mental, and social well-being of the community. Though the initial expense of comprehensive rehabilitation care may be high, the long-term cost is reduced because such care can prevent increased disability and dependency, and the more independent the patient, the lower the cost of care.

Howard A. Rusk described rehabilitation as the "third phase of medicine." If this is narrowly interpreted as tertiary prevention, it would suggest that rehabilitation follows primary and secondary prevention and its role in personal health care is a passive one. Rehabilitation is not third in order of health care but the third element of medicine. The future of rehabilitation medicine will be its contribution to the total health and welfare of the community as well as to that of the individual. It is perhaps more accurate to call rehabilitation the "third dimension of medicine" and place it side by side with public health and clinical medicine.

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